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ABSTRACT

Designing or making changes in things students use or wear is the challenge of this Unified Sciences and Mathematics for Elementary Schools (USMES) unit. The challenge is general enough to apply to many problem-solving situations in mathematics, science, social science, and language arts at any elementary school level (grades 1-8). The Teacher Resource Book for the unit is divided into five sections. Section I describes the USMES approach to student-initiated investigations of real problems, including a discussion of the nature of USMES "challenges." Section II provides an overview of possible student activities with comments on prerequisite skills, instructional strategies, suggestions when using the unit with primary grades, flow charts illustrating how investigations evolve from students' discussions of pertinent problems, and a hypothetical account of intermediate-level class activities. Section III provides documented events of actual class activities from grades 3, 4-5, 5, and 6. Section IV includes lists of "How To" cards and background papers, bibliography of non-USMES materials, and a glossary. Section V consists of charts identifying skills, concepts, processes, and areas of study learned as students become involved with the investigations. (JN)

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UNIFIED SCIENCES AND MATHEMATICS FOR ELEMENTARY SCHOOLS:
Mathematics and the Natural, Social, and Communications Sciences in Real Problem Solving.

Designing for Human Proportions

Education Development Center, Inc.
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Trial Edition

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CHALLENGE: DESIGN OR MAKE CHANGES IN THINGS THAT YOU USE OR WEAR SO THAT THEY WILL BE A GOOD FIT.

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Preface

The USMES Project

Unified Sciences and Mathematics for Elementary Schools: Mathematics and the Natural, Social, and Communications Sciences in Real Problem Solving (USMES) was formed in response to the recommendations of the 1967 Cambridge Conference on the Correlation of Science and Mathematics in the Schools.* Since its inception in 1970, USMES has been funded by the National Science Foundation to develop and carry out field trials of interdisciplinary units centered on long-range investigations of real and practical problems (or "challenges") taken from the local school/community environment. School planners can use these units to design a flexible curriculum for grades one through eight in which real problem solving plays an important role.

Development and field trials were carried out by teachers and students in the classroom with the assistance of university specialists at workshops and at occasional other meetings. The work was coordinated by a staff at the Education Development Center in Newton, Massachusetts. In addition, the staff at EDC coordinated implementation programs involving schools, districts, and colleges that are carrying out local USMES implementation programs for teachers and schools in their area.

Trial editions of the following units are currently available:

- Advertising
- Bicycle Transportation
- Classroom Design
- Classroom Management
- Consumer Research
- Describing People
- Designing for Human Proportions
- #Design Lab Design
- #Eating in School
- Getting There
- Growing Plants
- Manufacturing
- Mass Communications
- Nature Trails
- Orientation
- Pedestrian Crossings
- Play Area Design and Use
- Protecting Property
- #School Rules
- School Supplies
- School Zoo
- Soft Drink Design
- Traffic Flow
- #Using Free Time
- Ways to Learn/Teach
- Weather Predictions

*See *Goals for the Correlation of Elementary Science and Mathematics*, Houghton Mifflin Co., Boston, 1969.

#Available fall 1976.

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USMES Resources

In responding to a long-range challenge, the students and teachers often have need of a wide range of resources. In fact, all of the people and materials in the school and community are important resources for USMES activities. USMES provides resources in addition to these. One resource for students is the Design Lab or its classroom equivalent: using the tools and supplies available, children can follow through on their ideas by constructing measuring tools, testing apparatus, models, etc. Another resource for students is the *"How To" Cards*. Each set of cards gives information about a specific problem; the students use a set only when they want help on that particular problem.

Several types of resources are available for teachers: the *USMES Guide*, a *Teacher Resource Book* for each challenge, *Background Papers*, a *Design Lab Manual*, and a *Curriculum Correlation Guide*. A complete set of all these written materials comprise what is called the USMES library. This library, which should be available in each school using USMES units, contains the following:

1. *The USMES Guide*

   The USMES Guide is a compilation of materials that may be used for long-range planning of a curriculum that incorporates the USMES program. In addition to basic information about the project, the challenges, and related materials, it contains charts assessing the strengths of the various challenges in terms of their possible subject area content.

2. *Teacher Resource Books* (one for each challenge)

   Each book contains a description of the USMES approach to real problem-solving activities, general information about the particular unit, edited logs of class activities, other written materials relevant to the unit, and charts that indicate the basic skills, processes, and areas of study that may be learned and utilized as students become engaged in certain possible activities.

3. *Design Lab Manual*

   This contains sections on the style of Design Lab activities, safety considerations, and an inventory

of tools and supplies. Because many "hands-on" activities may take place in the classroom, the Design Lab Manual should be made available to each USMES teacher.

4. *"How To" Cards*

   These short sets of cards provide information to students about specific problems that may arise during USMES units. Particular computation, graphing, and construction problems are discussed. A complete list of the "How To" Cards can be found in the USMES Guide.

5. *Background Papers*

   These papers are written to provide information for the teachers on technical problems that might arise as students carry on various investigations. A complete list of the Background Papers can be found in the USMES Guide.

6. *Curriculum Correlation Guide*

   This volume is intended to coordinate other curriculum materials with the Teacher Resource Books and to provide the teacher with the means to integrate USMES easily into other school activities and lessons.

The preceding materials are described in brief in the USMES brochure, which can be used by teachers and administrators to disseminate information about the program to the local community. A variety of other dissemination and implementation materials are also available for individuals and groups involved in local implementation programs. They include *Preparing People for USMES: An Implementation Resource Book*, the USMES slide/tape show, the Design Lab slide/tape show, the Design Lab brochure, the USMES newsletter, videotapes of classroom activities, a general report on evaluation results, a map showing the locations of schools conducting local implementation of USMES, a list of experienced USMES teachers and university consultants, and newspaper and magazine articles.

Acknowledgments

Besides the contributors listed at the beginning of the book, we are deeply indebted to the many elementary school

children whose investigations of the challenge form the basis for this book. Without their efforts this book would not have been possible. Many thanks to the Planning Committee for their years of service and advice. Many thanks also to other members of the USMES staff for their suggestions and advice and for their help in staffing and organizing the development workshops. Special thanks also go to Christopher Hale for his efforts as Project Manager during the development of this book.

* * *

Because Tri-Wall was the only readily available brand of three layered cardboard at the time the project began, USMES has used it at workshops and in schools; consequently, references to Tri-Wall can be found throughout the Teacher Resource Books. The addresses of companies that supply three-layered cardboard can be found in the Design Lab Manual.

Introduction

Using the Teacher Resource Book

When teachers try a new curriculum for the first time, they need to understand the philosophy behind the curriculum. The USMES approach to student-initiated investigations of real problems is outlined in section A of this Teacher Resource Book.

Section B starts with a brief overview of possible student activities arising from the challenge; comments on prerequisite skills are included. Following that is a discussion of the classroom strategy for USMES real problem-solving activities, including introduction of the challenge, student activity, resources, and Design Lab use. Subsequent pages include a description of the use of the unit in primary grades, a flow chart and a composite log that indicate the range of possible student work, and a list of questions that the teacher may find useful for focusing the students' activities on the challenge.

Because students initiate all the activities in response to the challenge and because the work of one class may differ from that undertaken by other classes, teachers familiar with USMES need to read only sections A and B before introducing the challenge to students.

Section C of this book is the documentation section. These edited teachers' logs show the variety of ways in which students in different classes have worked at finding a solution to the challenge.

Section D contains a list of the titles of relevant sets of "How To" Cards and brief descriptions of the Background Papers pertaining to the unit. Also included in section D is a glossary of the terms used in the Teacher Resource Book and an annotated bibliography.

Section E contains charts that indicate the comparative strengths of the unit in terms of real problem solving, mathematics, science, social science, and language arts. It also contains a list of explicit examples of real problem solving and other subject area skills, processes, and areas of study learned and utilized in the unit. These charts and lists are based on documentation of activities that have taken place in USMES classes. Knowing ahead of time which basic skills and processes are likely to be utilized, teachers can postpone teaching that part of their regular program until later in the year. At that time students can study them in the usual way if they have not already learned them as part of their USMES activities.

A. Real Problem Solving and USMES

*If life were of such a constant nature that there were only a few chores to do and they were done over and over in exactly the same way, the case for knowing how to solve problems would not be so compelling. All one would have to do would be to learn how to do the few jobs at the outset. From then on he could rely on memory and habit. Fortunately--or unfortunately depending upon one's point of view--life is not simple and unchanging. Rather it is changing so rapidly that about all we can predict is that things will be different in the future. In such a world the ability to adjust and to solve one's problems is of paramount importance.**

Real Problem Solving

USMES is based on the beliefs that real problem solving is an important skill to be learned and that many math, science, social science, and language arts skills may be learned more quickly and easily within the context of student investigations of real problems. Real problem solving, as exemplified by USMES, implies a style of education which involves students in investigating and solving real problems. It provides the bridge between the abstractions of the school curriculum and the world of the student. Each USMES unit presents a problem in the form of a challenge that is interesting to children because it is both real and practical. The problem is real in several respects: (1) the problem applies to some aspect of student life in the school or community, (2) a solution is needed and not presently known, at least for the particular case in question, (3) the students must consider the entire situation with all the accompanying variables and complexities, and (4) the problem is such that the work done by the students can lead to some improvement in the situation. This expectation of useful accomplishment provides the motivation for children to carry out the comprehensive investigations needed to find some solution to the challenge.

The level at which the children approach the problems, the investigations that they carry out, and the solutions

*Kenneth B. Henderson and Robert E. Pingry, "Problem-Solving in Mathematics," in *The Learning of Mathematics: Its Theory and Practice,* Twenty-first Yearbook of the National Council of Teachers of Mathematics (Washington, D.C.: The Council, 1953), p. 233.

The USMES Approach

that they devise may vary according to the age and ability of the children. However, real problem solving involves them, at some level, in all aspects of the problem-solving process: definition of the problem; determination of the important factors in the problem; observation; measurement; collection of data; analysis of the data using graphs, charts, statistics, or whatever means the students can find; discussion; formulation and trial of suggested solutions; clarification of values; decision making; and communications of findings to others. In addition, students become more inquisitive, more cooperative in working with others, more critical in their thinking, more self-reliant, and more interested in helping to improve social conditions.

To learn the process of real problem solving, the students must encounter, formulate, and find some solution to complete and realistic problems. The students themselves, not the teacher, must analyze the problem, choose the variables that should be investigated, search out the facts, and judge the correctness of their hypotheses and conclusions. In real problem-solving activities, the teacher acts as a coordinator and collaborator, not an authoritative answer-giver.

The problem is first reworded by students in specific terms that apply to their school or community, and the various aspects of the problem are discussed by the class. The students then suggest approaches to the problem and set priorities for the investigations they plan to carry out. A typical USMES class consists of several groups working on different aspects of the problem. As the groups report periodically to the class on their progress, new directions are identified and new task forces are formed as needed. Thus, work on an USMES challenge provides students with a "discovery-learning" or "action-oriented" experience.

Real problem solving does not rely solely on the discovery-learning concept. In the real world people have access to certain facts and techniques when they recognize the need for them. The same should be true in the classroom. When the students find that certain facts and skills are necessary for continuing their investigation, they learn willingly and quickly in a more directed way to acquire these facts and skills. Consequently, the students should have available different resources that they may use as they recognize the need for them, but they should still be left with a wide scope to explore their own ideas and methods.

Certain information on specific skills is provided by the sets of USMES "How To" Cards. The students are referred only to the set for which they have clearly identified a need and only when they are unable to proceed on their own. Each "How To" Cards title clearly indicates the skill involved--"How to Use a Stopwatch," "How to Make a Bar Graph Picture of Your Data," etc. (A complete list of the "How To" Cards can be found in Chapter IX of the USMES Guide.)

Another resource provided by USMES is the Design Lab or its classroom equivalent. The Design Lab provides a central location for tools and materials where devices may be constructed and tested without appreciably disrupting other classroom activities. Ideally, it is a separate room with space for all necessary supplies and equipment and work space for the children. However, it may be as small as a corner of the classroom and may contain only a few tools and supplies. Since the benefits of real problem solving can be obtained by the students only if they have a means to follow up their ideas, the availability of a Design Lab can be a very important asset.

Optimally, the operation of the school's Design Lab should be such as to make it available to the students whenever they need it. It should be as free as possible from set scheduling or programming. The students use the Design Lab to try out their own ideas and/or to design, construct, test, and improve many devices initiated by their responses to the USMES challenges. While this optimum operation of the Design Lab may not always be possible due to various limitations, "hands-on" activities may take place in the classroom even though a Design Lab may not be available. (A detailed discussion of the Design Lab can be found in Chapter VI of the USMES Guide, while a complete list of "How To" Cards covering such Design Lab skills as sawing, gluing, nailing, soldering, is contained in Chapter IX.)

Work on all USMES challenges is not only sufficiently complex to require the collaboration of the whole class but also diverse enough to enable each student to contribute according to his/her interest and ability. However, it should be noted that if fewer than ten to twelve students from the class are carrying out the investigation of a unit challenge, the extent of their discovery and learning can be expected to be less than if more members of the class are involved. While it is possible for a class to work on two related units at the same time, in many classes the students progress better with just one.

The amount of time spent each week working on an USMES challenge is crucial to a successful resolution of the

problem. Each challenge is designed so that the various investigations will take from thirty to forty-five hours, depending on the age of the children, before some solution to the problem is found and some action is taken on the results of the investigations. Unless sessions are held at least two or three times a week, it is difficult for the children to maintain their interest and momentum and to become involved intensively with the challenge. The length of each session depends upon the age level of the children and the nature of the challenge. For example, children in the primary grades may proceed better by working on the challenge more frequently for shorter periods of time, perhaps fifteen to twenty minutes, while older children may proceed better by working less frequently for much longer periods of time.

Student interest and the overall accomplishments of the class in finding and implementing solutions to the challenge indicate when the class's general participation in unit activities should end. (Premature discontinuance of work on a specific challenge is often due more to waning interest on the part of the teacher than to that of the students.) However, some students may continue work on a voluntary basis on one problem, while the others begin to identify possible approaches to another USMES challenge.

Importance of the Challenge

Although individual (or group) discovery and student initiation of investigations is the process in USMES units, this does not imply the constant encouragement of random activity. Random activity has an important place in children's learning, and opportunities for it should be made available at various times. During USMES activities, however, it is believed that children learn to solve real problems only when their efforts are focused on finding some solution to the real and practical problem presented in the USMES challenge. It has been found that students are motivated to overcome many difficulties and frustrations in their efforts to achieve the goal of effecting some change or at least of providing some useful information to others. Because the children's commitment to finding a solution to the challenge is one of the keys to successful USMES work, it is extremely important that the challenge be introduced so that it is accepted by the class as an important problem to which they are willing to devote a considerable amount of time.

The challenge not only motivates the children by stating the problem but also provides them with a criterion for judging their results. This criterion--if it works, it's right (or if it helps us find an answer to our problem, it's

a good thing to do)--gives the children's ideas and results a meaning within the context of their goal. Many teachers have found this concept to be a valuable strategy that not only allows the teacher to respond positively to all of the children's ideas but also helps the children themselves to judge the value of their efforts.

Role of the Teacher

With all of the above in mind, it can be said that the teacher's responsibility in the USMES strategy for open classroom activities is as follows:

1. Introduce the challenge in a meaningful way that not only allows the children to relate it to their particular situation but also opens up various avenues of approach.

2. Act as a coordinator and collaborator. Assist, not direct, individuals or groups of students as they investigate different aspects of the problem.

3. Hold USMES sessions at least two or three times a week so that the children have a chance to become involved in the challenge and carry out comprehensive investigations.

4. Provide the tools and supplies necessary for initial hands-on work in the classroom or make arrangements for the children to work in the Design Lab.

5. Be patient in letting the children make their own mistakes and find their own way. Offer assistance or point out sources of help for specific information (such as the "How To" Cards) only when the children become frustrated in their approach to the problem. Conduct skill sessions as necessary.

6. Provide frequent opportunities for group reports and student exchanges of ideas in class discussions. In most cases, students will, by their own critical examination of the procedures they have used, improve or set new directions in their investigations.

7. If necessary, ask appropriate questions to stimulate the students' thinking so that they will make more extensive and comprehensive investigations or analyses of their data.

8. Make sure that a sufficient number of students (usually ten to twelve) are working on the challenge so that activities do not become fragmented or stall.

Student success in USMES unit activities is indicated by the progress they make in finding some solution to the challenge, not by following a particular line of investigation nor by obtaining specified results. The teacher's role in the USMES strategy is to provide a classroom atmosphere in which all students can, in their own way, search out some solution to the challenge.

USMES in the Total School Program

Today many leading educators feel that real problem solving (under different names) is an important skill to be learned. In this mode of learning particular emphasis is placed on developing skills to deal with real problems rather than the skills needed to obtain "correct" answers to contrived problems. Because of this and because of the interdisciplinary nature of both the problems and the resultant investigations, USMES is ideal for use as an important part of the elementary school program. Much of the time normally spent in the class on the traditional approaches to math, science, social science, and language arts skills can be safely assigned to USMES activities. In fact, as much as one-fourth to one-third of the total school program might be allotted to work on USMES challenges. Teachers who have worked with USMES for several years have each succeeding year successfully assigned to USMES activities the learning of a greater number of traditional skills. In addition, reports have indicated that students retain for a long time the skills and concepts learned and practiced during USMES activities. Therefore, the time normally spent in reinforcing required skills can be greatly reduced if these skills are learned and practiced in the context of real problem solving.

Because real problem-solving activities cannot possibly cover all the skills and concepts in the major subject areas, other curricula as well as other learning modes (such as "lecture method," "individual study topics," or programmed instruction) need to be used in conjunction with USMES in an optimal education program. However, the other

instruction will be enhanced by the skills, motivation, and understanding provided by real problem solving, and, in some cases, work on an USMES challenge provides the context within which the skills and concepts of the major subject areas find application.

In order for real problem solving taught by USMES to have an optimal value in the school program, class time should be apportioned with reason and forethought, and the sequence of challenges investigated by students during their years in elementary school should involve them in a variety of skills and processes. Because all activities are initiated by students in response to the challenge, it is impossible to state unequivocally which activities will take place. However, it is possible to use the documentation of activities that have taken place in USMES trial classes to schedule instruction on the specific skills and processes required by the school system. Teachers can postpone the traditional way of teaching the skills that might come up in work on an USMES challenge until later in the year. At that time students can learn the required skills in the usual way if they have not already learned them during their USMES activities.

These basic skills, processes, and areas of study are listed in charts and lists contained in each Teacher Resource Book. A teacher can use these charts to decide on an overall allocation of class time between USMES and traditional learning in the major subject disciplines. Examples of individual skills and processes are also given so that the teacher can see beforehand which skills a student may encounter during the course of his investigations. These charts and lists may be found in section E.

Ways In Which USMES Differs From Other Curricula

As the foregoing indicates, USMES differs significantly from other curricula. Real problem solving develops the problem-solving ability of students and does it in a way (learning-by-doing) that leads to a full understanding of the process. Because of the following differences, some teacher preparation is necessary. Some teachers may have been introduced by other projects to several of the following new developments in education, but few teachers have integrated all of them into the new style of teaching and learning that real problem solving involves.

1. <u>New Area of Learning</u>--Real problem solving is a new area of learning, not just a new approach or a new content within an already-defined subject area. Although many subject-matter curricula

include something called problem solving, much of this problem solving involves contrived problems or fragments of a whole situation and does not require the cognitive skills needed for the investigation of real and practical problems. Learning the cognitive strategy required for real problem solving is different from other kinds of learning.

3. Interdisciplinary Education--Real problem solving integrates the disciplines in a natural way; there is no need to impose a multi-disciplinary structure. Solving real and practical problems requires the application of skills, concepts, and processes from many disciplines. The number and range of disciplines are unrestricted and the importance of each is demonstrated in working toward the solution of practical problems.

3. Student Planning--To learn the process of problem solving, the students themselves, not the teacher, must analyze the problem, choose the variables that should be investigated, search out the facts, and judge the correctness of the hypotheses and conclusions. In real problem-solving activities the teacher acts as a coordinator and collaborator, not as an authoritative source of answers.

4. Learning-by-Doing--Learning-by-doing, or discovery learning as it is sometimes called, comes about naturally in real problem solving since the problems tackled by each class have unique aspects; for example, different lunchrooms or pedestrian crossings have different problems associated with them and, consequently, unique solutions. The challenge, as defined in each situation, provides the focus for the children's hands-on learning experiences, such as collecting real data; constructing measuring instruments, scale models, test equipment, etc.; trying their suggested improvements; and (in some units) preparing reports and presentations of their findings for the proper authorities.

5. Learning Skills and Concepts as Needed--Skills and concepts are learned in real problem solving

as the need for them arises in the context of the work being done, rather than having a situation imposed by the teacher or the textbook being used. Teachers may direct this learning when the need for it arises, or students may search out information themselves from resources provided.

6. Group Work--Progress toward a solution to a real problem usually requires the efforts of groups of students, not just individual students working alone. Although some work may be done individually, the total group effort provides good opportunities for division of labor and exchange of ideas among the groups and individuals. The grouping is flexible and changes in order to meet the needs of the different stages of investigation.

7. Student Choice--Real problem solving offers classes the opportunity to work on problems that are real to them, not just to the adults who prepare the curriculum. In addition, students may choose to investigate particular aspects of the problem according to their interest. The variety of activities ensuing from the challenge allows each student to make some contribution towards the solution of the problem according to his or her ability and to learn specific skills at a time when he or she is ready for that particular intellectual structure.

B. General Papers on Designing for Human Proportions

1. OVERVIEW OF ACTIVITIES

Challenge:

Design or make changes in things that you use or wear so that they will be a good fit.

Possible Class Challenges:

Design tables that would be comfortable for students in your class.

Determine how many sizes of Design Lab smocks should be made for students in your school for comfort and reasonable cost.

On a day-to-day basis, children face the inconvenience of dealing with items that are either too small or too big. Small children may complain that everything is too big or too high; for example, the drinking fountain, pencil sharpener, and chalkboard are too high and the work smocks are too big. Tall children, however, may complain that everything is too low or too small, such as the tables and desks in the classroom. The Designing for Human Proportions challenge focuses the children's attention on the problem of what height or what size to make certain things for people of differing sizes.

After initial observation of a particular problem in the classroom, the class may identify several items that do not seem to fit properly or are of the wrong height. In considering ways to accommodate everyone in the class, the children may soon realize that the heights of some items, such as the drinking fountain and chalkboard, must accommodate everyone in that area or in the classroom. Other items, such as desks, community tables, and smocks, are more easily made in different sizes to accommodate various individuals.

To determine proper heights and sizes for a varied population, the children become involved with many aspects of measurement. The body dimension (such as length of reach in the case of chalkboards) or dimensions (in the case of clothing) that best determine a person's comfort range for use or wear is determined. Before measuring, the class may discuss which and how many people to measure. Some classes may explore different units of measure and then design and construct measuring tools in the Design Lab. The degree of accuracy needed for each type of measurement may then be considered.

The resulting data is graphed and analyzed. To see the spread of the measurements, the children may put the data on a histogram. Children trying to decide how high to place a chalkboard may decide to find the median reach of the class, determining at the same time how different the reaches of some children are from the median. Other children (such as those working on the heights for tables) may use the histogram to visually cluster the measurements on the graph into sizes that would accommodate the different-sized children in the class. Classes that must consider two body di-

mensions to determine sizes for clothing may plot scatter diagrams to investigate possible correlations between measurements of body parts.

The children may make a prototype or a full scale model to test their ideas on the new height of the board or on the fit of the smock. Some classes may submit their recommendations to the appropriate authority to have the chalkboard raised or lowered. Other classes may become involved in the actual design and production of items, such as tables or smocks.

The children's activities may lead naturally to other USMES challenges. Classes that want to produce furniture or items of clothing may investigate the Consumer Research challenge or the Manufacturing challenge (if the item is to be produced in quantity). Other classes may become interested in making more changes and may choose to investigate the Classroom Design, Play Area Design and Use, and Design Lab Design challenges. Still other classes may further investigate individual characteristics and tackle the Describing People challenge.

Although many of the Designing for Human Proportions activities may require skills and concepts new to the children, there is no need for preliminary work on them because the children can learn them when the need arises. In fact, children learn more quickly and easily when they see a need to learn. Consider counting: whereas children usually learn to count by rote, they can through USMES, gain a better understanding of counting by learning or practicing it within real contexts. In working on Designing for Human Proportions children also learn and practice graphing, measuring, working with decimals, and dividing. Although dividing seems necessary to compare fractions or ratios, primary children can make comparisons graphically; sets of data can also be compared graphically or by subtracting medians (half-way values). Furthermore, instead of using division to make scale drawings, younger children can convert their measurements to spaces on graph paper. Division may be introduced at the proper grade level during calculation of percentages or averages.

2. CLASSROOM STRATEGY FOR DESIGNING FOR HUMAN PROPORTIONS

Each USMES unit revolves around a challenge--a statement that says, "Solve this problem." The success or failure of the unit depends largely on (1) the relevance of the problem for the students and (2) the process by which they define and accept the challenge. If the children see the problem as a real one, they will be committed to finding a solution; they will have a focus and purpose for their activities. If the students do not think the problem affects them, their attempts at finding solutions will likely be disjointed and cursory.

The Designing for Human Proportions challenge as stated in the Teacher Resource Book is general enough to apply to many situations. Students in different classes define and reword the challenge to fit their particular situation and thus arrive at a specific class challenge. For example, the Designing for Human Proportions challenge--Design or make changes in things that you use or wear so that they will be a good fit--has been restated by one class in terms of designing a workbench that would be a suitable height for everyone in the class. Another class worked on the challenge of designing and making Design Lab aprons that would fit students of different sizes in the school.

The Process of Introducing the Challenge

Given that a problem exists, how can a teacher, without being directive, help the students identify the challenge that they will work on as a group? There is no set method because of variations among teachers, classes, and schools and among the USMES units themselves. However, USMES teachers have found that certain general techniques in introducing the challenge are helpful.

One such technique is to turn a discussion of some recent event toward the challenge. For example, the teacher may focus a discussion of the uncomfortableness of classroom furniture or the inconvenient heights of building fixtures on the Designing for Human Proportions challenge.

One fourth-grade teacher focused a discussion of ill-fitting clothing on the Designing for Human Proportions challenge. The discussion arose when one boy complained of receiving a jacket for Christmas that did not fit. Other students talked about clothes they had received and commented that most fit except for the length. The class discussed human proportions and then were challenged to redesign something that they used or wore so that it would be a better fit.

Often work on one challenge leads to another.

While working on an Eating in School challenge, one fifth-grade class obtained permission from the dietitian to post the luncheon menu in the lunchroom. When it came time to hang the menu, however, the children realized that they had to put it at a height suitable for all the students in the school. They decided to obtain the mean eye-level height of all the children in the school. Rather than measure everyone's eye-level height, the class decided to measure every fifth student from the alphabetical class list.

The need for a sturdy worktable arose in one fourth-grade class while working on a Weather Predictions challenge. The children became frustrated trying to make their weather instruments on top of their small desks. A group was formed to make a table that would be a suitable height for everyone in the class.

When children encounter a problem that leads to a related USMES challenge, one group of children may begin work on the second challenge while the rest of the class continues with the first challenge. However, there should be at least ten to twelve students working on any one challenge; otherwise, the children's work may be fragmented or superficial or may break down completely.

Sometimes the discussion of a broad problem may encompass the challenges of several related units. For example, a discussion of problems in the classroom may lead to Classroom Design, Classroom Management, Designing for Human Proportions, Protecting Property, or Using Free Time.

An experienced USMES teacher is usually willing to have the children work on any one of the several challenges that may arise during the discussion of a broad problem. While this approach gives the children the opportunity to select the challenge they are most interested in investigating, it does place on the teacher the additional responsibility of being prepared to act as a resource person for whichever challenge is chosen.

Classroom experience has shown that children's progress on the Designing for Human Proportions challenge may be poor if the teacher and students do not reach a common understanding of what their challenge is before beginning work on it. Having no shared focus for their work, the children will lack the motivation inherent in working together to solve a real problem. As a result, they may quickly lose interest.

Activities in one sixth-grade class strayed from the Designing for Human Proportions challenge because the teacher and students did not agree on a specific challenge before beginning work. The class compared different-sized chairs and discussed body proportions in relation to the unit challenge. Wanting the children to expand further their discussion of body proportions, the teacher asked the class how they could change the room to increase comfort. The class decided that more space was needed in the room and became involved in furniture rearrangement. Later, when the class was in the Design Lab, several children began making chairs.

A similar situation occurs if the teacher, rather than ensuring that the children have agreed upon a challenge, merely assigns a series of activities. Although the teacher may see how these activities relate to an overall goal, the children may not.

In one fourth-grade class the teacher never introduced the Designing for Human Proportions challenge. Activities that followed occurred at random. The children measured and compared their heights and weights. They also measured various body parts to compare body proportions and drew a scaled picture of themselves. When they went to the Design Lab, the girls made clothes for their Tri-Wall figures while the boys made go-carts for their figures.

Initial Work on the Challenge

Once a class has decided to work on a Designing for Human Proportions challenge, USMES sessions should be held several times a week, but they need not be rigidly scheduled. When sessions are held after long intervals, students often have

difficulty remembering exactly where they were in their investigations and momentum diminishes.

During initial sessions the students list possible ways that the item they have selected to design or change may be made to fit people of different sizes. This procedure is often combined with or followed by preliminary observations and/or opinion surveys. The class then sets priorities for the tasks they consider necessary to complete their plans. Most of these tasks are carried out by small groups of children. As various groups complete their work, their members join other groups or form new groups to work on additional tasks.

Students in one sixth-grade class identified the need for Design Lab aprons. Major tasks that were identified, such as measuring students in all the grades, graphing and analyzing the data, and making and selling the aprons, were carried out by small groups. As one group completed its tasks, the students joined another group.

However, if too many groups are formed, work on the challenge can become fragmented. The teacher finds it impossible to be aware of the progress and problems of each group; in addition, the small number of students in each group lessens the chance for varied input and interaction.

One combination fourth/fifth/sixth-grade class was challenged to make things based on human proportions that could be sold at the upcoming school fair. Six small groups were formed; many groups had only two or three members. Although enthusiasm remained high the class was unable to examine thoroughly various aspects of the challenge.

Refocusing on the Challenge

As the class works on the challenge, the children's attention should, from time to time, be refocused on it so that they do not lose sight of their overall goal. Refocusing is particularly important with younger children because they have a shorter attention span. Teachers find it helpful to hold periodic class discussions that include group reports. Such sessions help the students review what

they have accomplished and what they still need to do in order to carry out their proposed changes. These discussions also provide an opportunity for students to participate both in evaluating their own work and in exchanging ideas with their classmates. (Another consequence of having too many groups is that not every group can be given enough time to report to the class, thereby increasing the possibility that the children's efforts will overlap unnecessarily.)

Class discussions for one fifth-grade class served as a means of reviewing group work and sharing ideas. In redesigning the classroom sink to accommodate most of the fourth/fifth/sixth-graders, the class broke into three groups to collect the needed measurements. However, after the measurements were collected, the class as a whole discussed what to do with the data. The children then broke into groups again to graph the data and later reconvened to discuss their findings and to plan their next tasks.

Resources for Work on the Challenge

When children try to decide on solutions before collecting and analyzing enough data or encounter difficulties during their investigations, an USMES teacher helps out. Instead of giving answers or suggesting specific procedures, the teacher asks open-ended questions that stimulate the students to think more comprehensively and creatively about their work. For example, instead of telling the students that they will need to make several table heights to accomodate their large population, the teacher may ask, "What is the range of the measurements?" "Is the mean height going to be comfortable for the shortest students?" "If not, how can we accommodate the shorter students?" Examples of other nondirective, thought-provoking questions may be found in section B6 of this resource book.

The teacher may also refer students to the "How To" Cards which provide information about specific skills, such as drawing graphs or analyzing data. If many students, or even the entire class, need help in particular areas, such as using fractions, the teacher should conduct skill sessions as these needs arise. (Background Papers provide teachers with additional information on general topics applicable to most challenges.)

USMES teachers can also assist students by making it possible for them to carry out tasks involving hands-on activities. If children need to collect data outside of their classroom--on the playground or in the local store--the teacher can help with scheduling and supervision. If the children's tasks require them to design and construct items, the teacher should make sure that they have access to a Design Lab. Any collection of tools and materials kept in a central location (in part of the classroom, on a portable cart, or in a separate room) can be called a Design Lab.

Valuable as it is, a Design Lab is not necessary to begin work on a Designing for Human Proportions challenge. The lab is used only when needed, and this need may not arise during early work on the challenge. To carry out construction activities in schools without Design Labs, students may scrounge or borrow tools and supplies from parents, local businesses, or other members of the community.

At times some classes may not need to use the Design Lab at all; the extent to which the Design Lab is used varies with different classes and different units because the children themselves determine the direction of the investigations and because construction activities are more likely to occur in some units than in others.

The sixth-grade class that made the Design Lab aprons did not need to use the Design Lab even though there was one in the school. After determining the number of sizes to make, the students bought the material, cut the aprons out according to the patterns, and sewed them on machines that were brought into the classroom.

Culminating Activities

Student investigations generally continue until the children have agreed upon and implemented some solution to their problem. They may write letters to officials or retailers describing the data they have collected and recommending a course of action.

One sixth-grade class was frustrated because the frequently used mirrors near their classroom were too low for them. The students measured their heights and based on their analysis of the data made recommendations to the principal. Several days later the

mirror heights were changed according to their recommended changes.

One third-grade class determined the shoe sizes and style preferences of the primary students in their school. Surveys were conducted and measurements taken. The children then wrote letters to some of the local stores to share the information they had collected.

3. USE OF DESIGNING FOR HUMAN PROPORTIONS IN THE PRIMARY GRADES

Children in primary grades may make significant progress with the Designing for Human Proportions challenge of designing or making changes in things that they use or wear so that the items will be a good fit. Although their entry level to the challenge and their sophistication with the investigation will certainly be different from that of older children, they will be able to propose possible solutions, collect and interpret data, and take effective action to meet their challenge.

Since small children are always eager to share their experiences, a teacher may wait for an incident or a topic to arise from the children before introducing the problem of the challenge. The topic of comfortable fit may arise soon after school begins as the children try to find desks and chairs that properly fit them, or the class may discuss all the clothing that is too big or too small that they received after a holiday or a birthday. In one third-grade class the topic of shoe comfort arose after one girl forgot to bring her sneakers to school for gym class and had to restrict her activities because she was wearing clogs. Such events will provide the basis for a lively discussion as small children know all too well the problems of coping in an adult world.

From the many problems suggested, the class may identify one that they wish to tackle first. Tasks are identified, and in classes where the children are familiar with small group work, groups are formed. With less experienced children the teacher may find it beneficial in the beginning for the whole class to work on one problem at a time. Gradually, as the children become more able to follow through on their proposed plans, the teacher may encourage the class to divide the various aspects of the problem among small groups.

In addition to being efficient, small group work also provides for the opportunity to practice oral skills and for the exchange of ideas. After completing their investigations, the members of a group organize their findings and then present them to the class for discussion. Other language arts skills are learned as the children design and administer attitudinal surveys, make posters to advertise articles they may have made, and write letters to various authorities to share their findings and/or propose changes.

Through class discussions and group work, the children may note the range of opinions among their classmates. The survey is seen as an important vehicle for gathering these individual opinions. The children compile simple questions, decide upon a sample size, and organize an efficient way to administer the survey. The survey may be conducted within the classroom or among other classes. One third-grade class conducted a survey on shoe style preference among the second- and third-grade classes in their school. They wrote the questions and decided that the most efficient way to administer the survey was to have one group handle one class.

The Designing for Human Proportions unit provides opportunities for children to become involved with various aspects of measurement, such as units of measure, different measuring tools, and measurement reliability and accuracy. Children quickly see the need for some sort of a unit of measurement when they realize that visual approximations or measurements using different units are difficult to compare. Children in one second-grade class measured each other's heights using different hand lengths. The class noted afterwards that the heights could not be compared because they were expressed in several different hand lengths. The children decided that to compare the heights, they must measure everyone using the same unit of measure or the same hand length.

Small children are quick to perceive discrepancies in measurements. In one third-grade class, one child noted that he was taller than another student but the other student's measurement was larger. The class discussed all the variables that could have affected the measurement: not everyone took his shoes off, some children "stretched" themselves a little, measurers did not place their measuring instruments precisely on the floor, measuring tapes were not held straight, and measuring instruments were accidently moved.

Tallying and graphing are easily introduced to primary children as they see the need to organize and make pictures of their information. One third-grade class made a tally of

foot sizes in the class by placing large sheets of paper on the floor. In the upper left corner of each sheet, a pre-measured rectangle was placed. Each child looked for the rectangle that best fit his foot by placing his foot in each rectangle. When the appropriate rectangle size was found, he placed a cut-out tracing of his foot on that sheet of paper. The children were able to see the most and least common foot sizes from the resultant pictograph. The range of foot sizes was also noted. This same class also made bar graphs of their survey data on shoe style preference. Again, the children were able to determine from the graphs which shoe style was most popular in the different grades.

Often times small children need to compare ratios or fractions. Comparison may be made and comprehended by the children without using division by the construction of a graph called a slope diagram.* Each ratio may be plotted on the graph form; a line from each plotted point to the origin is drawn. The ratios are then compared visually by comparing the slopes of the different lines.

Experience in many schools has shown that primary children are able to work in the Design Lab and are able to use the power tools with some adult assistance. Students in one second grade made Tri-Wall tables, both round and diamond-shaped. Other primary classes have made bookshelves, Tri-Wall sandals, and puppet theaters.

4. FLOW CHART

The following flow charts represent some of the student activities--discussions, observations, calculations, constructions--that may occur during work on the Designing for Human Proportions challenge. Because each class will choose its own approach to the challenge, the sequences of events given here represent only a few of the many possible variations. Furthermore, no one class is expected to undertake all the activities listed; a class usually works on just one of the aspects represented by the several charts.

The flow chart is not a lesson plan and should not be used as one. Instead it illustrates how comprehensive investigations evolve from the students' discussion of a problem.

*Formerly called triangle diagram.

Challenge: Design or make changes in things that you use or wear so that they will be a good fit.

Optional Preliminary Activities

USMES Units:
- *Describing People*
- *Design Lab Design*
- *Classroom Design*
- *Manufacturing*
- *Play Area Design and Use*

Social Studies Unit on Production of items that must accommodate a large population

Gulliver's Travels Activities

Possible Student Activities

Class Discussion: What are some of the problems you have in finding a comfortable chair and desk when you first come to school? What other items do not seem to fit properly or do not seem the proper height for you?

Data Collection: General observation of school fixtures and furniture to determine suitability of height and size for children. Observation of different sizes and styles of clothing to determine proper fit.

Data Collection: Class survey to determine comfortableness of clothing and school furniture and heights of room fixtures.

Data Representation: Compiling survey results. Preparation of bar graphs.

Class Discussion: Reports from groups. Analysis and interpretation of observation data and graphs. Discussion of what changes are feasible. Assignment of priorities to different problems.

Investigation of items that must accommodate everyone in the room; e.g., chalkboard, pencil sharpener drinking fountain, light switches.

See Flow Chart A.

Investigation of items that come in different sizes and that require consideration of one body measurement to determine sizes, e.g., tables, desks, wristbands, belts, hats.

See Flow Chart B.

Investigation of items that come in different sizes and that require consideration of more than one body measurement to determine sizes; e.g., shirts, shoes, work aprons.

See Flow Chart C.

Presentation to principal to institute change. Construction of items.

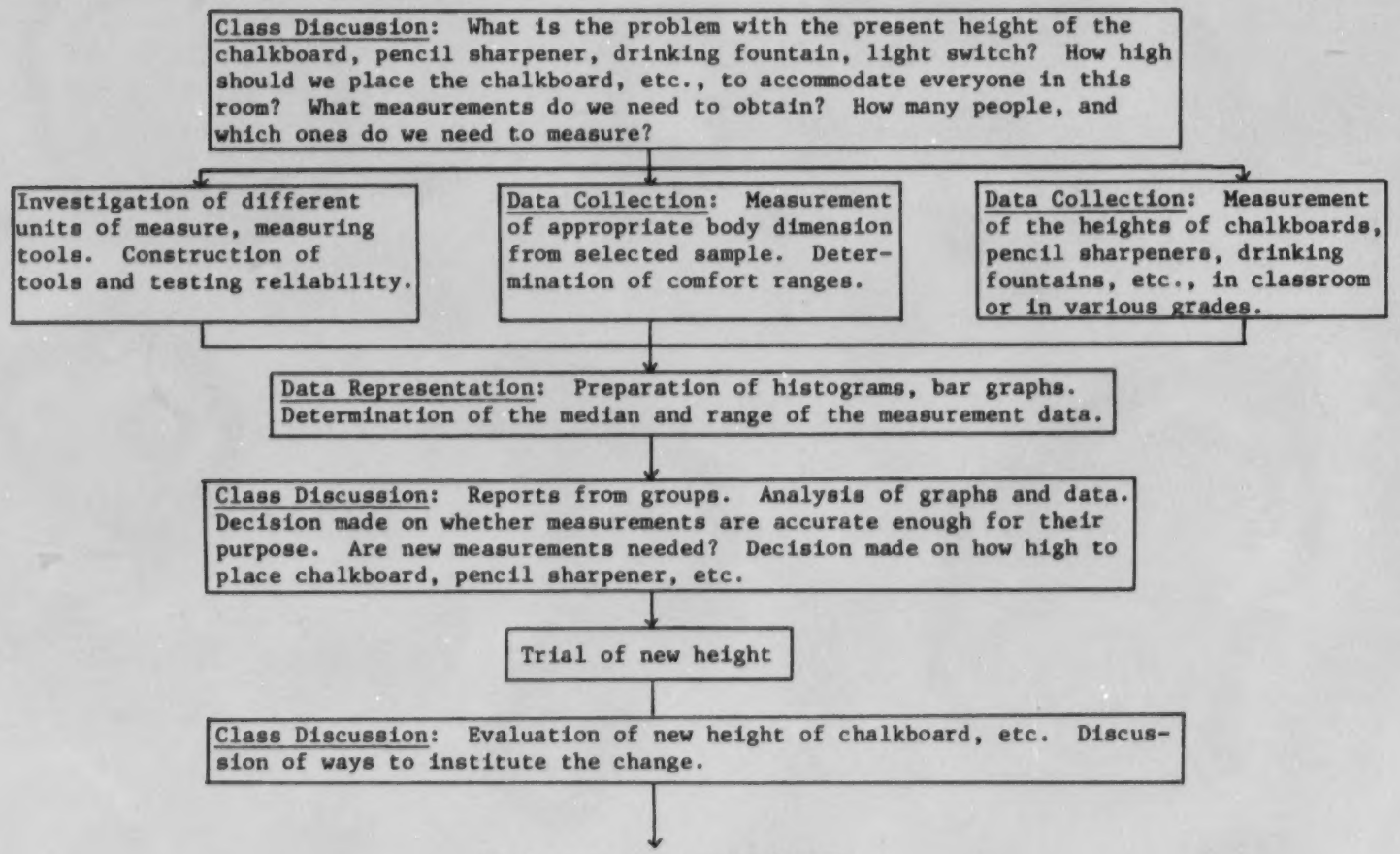
Consideration of other items that do not fit properly or are an uncomfortable height.

Optional Follow-Up Activities:

USMES Units:
- *Describing People*
- *Design Lab Design*
- *Manufacturing*
- *Classroom Design*
- *Consumer Research*
- *Play Area Design and Use*

FLOW CHART A

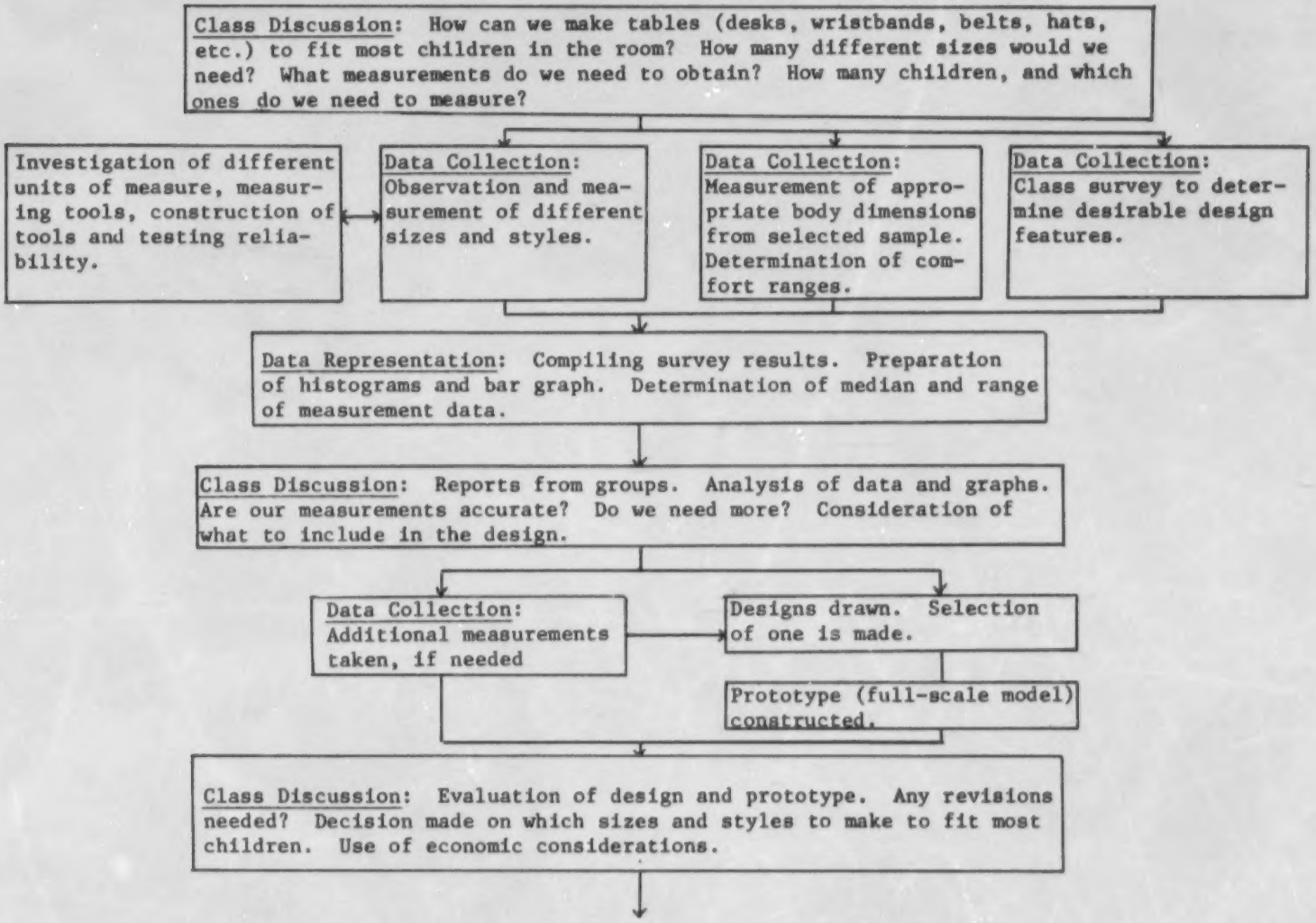
Items that Must Accommodate Everyone


Class Discussion: What is the problem with the present height of the chalkboard, pencil sharpener, drinking fountain, light switch? How high should we place the chalkboard, etc., to accommodate everyone in this room? What measurements do we need to obtain? How many people, and which ones do we need to measure?
Investigation of different units of measure, measuring tools. Construction of tools and testing reliability.
Data Collection: Measurement of appropriate body dimension from selected sample. Determination of comfort ranges.
Data Collection: Measurement of the heights of chalkboards, pencil sharpeners, drinking fountains, etc., in classroom or in various grades.
Data Representation: Preparation of histograms, bar graphs. Determination of the median and range of the measurement data.
Class Discussion: Reports from groups. Analysis of graphs and data. Decision made on whether measurements are accurate enough for their purpose. Are new measurements needed? Decision made on how high to place chalkboard, pencil sharpener, etc.
Trial of new height
Class Discussion: Evaluation of new height of chalkboard, etc. Discussion of ways to institute the change.

(Return to main flow chart.)

FLOW CHART B

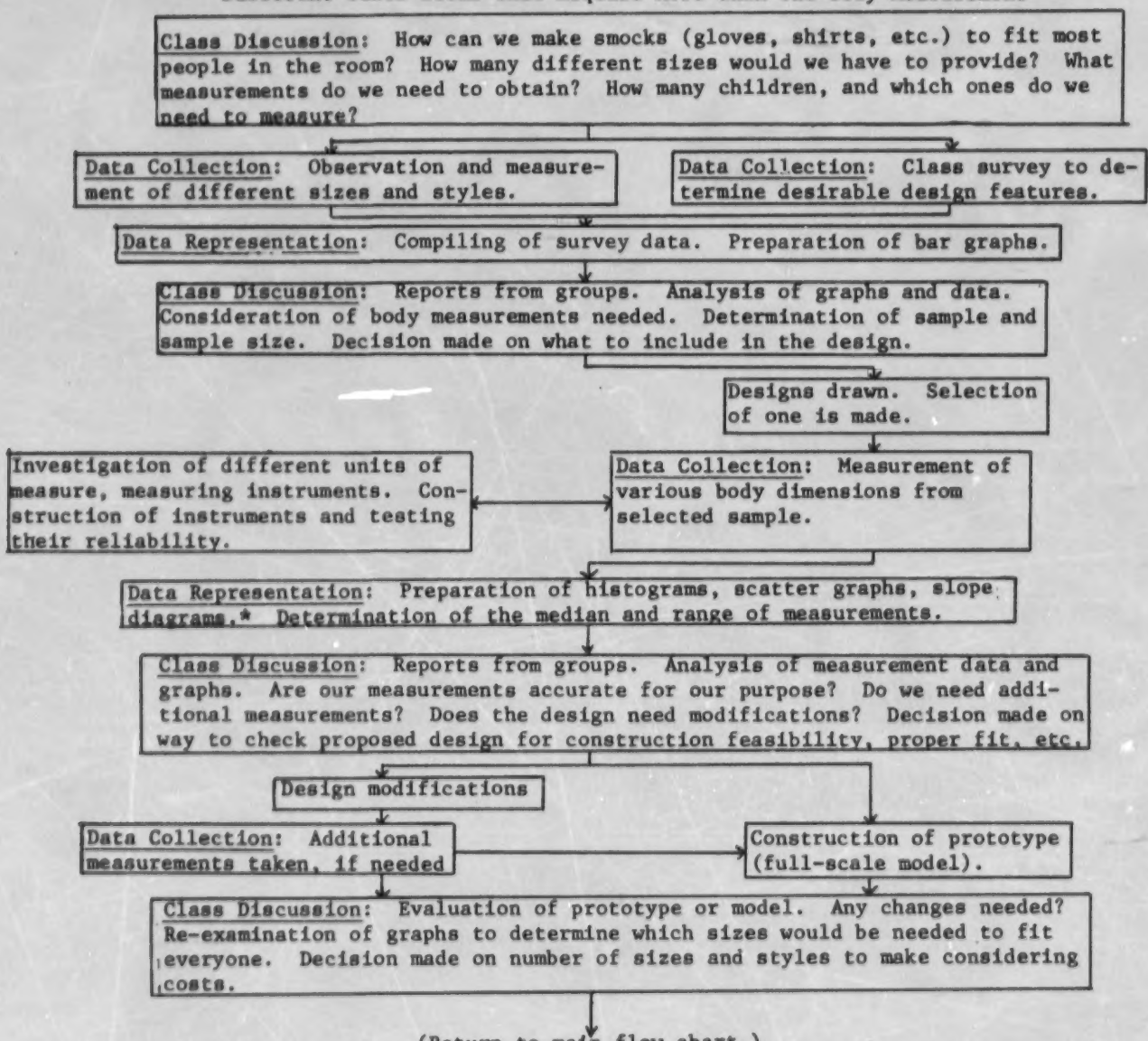
Different Sized Items that Require One Body Measurement


Class Discussion: How can we make tables (desks, wristbands, belts, hats, etc.) to fit most children in the room? How many different sizes would we need? What measurements do we need to obtain? How many children, and which ones do we need to measure?
Investigation of different units of measure, measuring tools, construction of tools and testing reliability.
Data Collection: Observation and measurement of different sizes and styles.
Data Collection: Measurement of appropriate body dimensions from selected sample. Determination of comfort ranges.
Data Collection: Class survey to determine desirable design features.
Data Representation: Compiling survey results. Preparation of histograms and bar graph. Determination of median and range of measurement data.
Class Discussion: Reports from groups. Analysis of data and graphs. Are our measurements accurate? Do we need more? Consideration of what to include in the design.
Data Collection: Additional measurements taken, if needed
Designs drawn. Selection of one is made.
Prototype (full-scale model) constructed.
Class Discussion: Evaluation of design and prototype. Any revisions needed? Decision made on which sizes and styles to make to fit most children. Use of economic considerations.

(Return to main flow chart.)

FLOW CHART C

Different Sized Items that Require More than One Body Measurement


Class Discussion: How can we make smocks (gloves, shirts, etc.) to fit most people in the room? How many different sizes would we have to provide? What measurements do we need to obtain? How many children, and which ones do we need to measure?
Data Collection: Observation and measurement of different sizes and styles.
Data Collection: Class survey to determine desirable design features.
Data Representation: Compiling of survey data. Preparation of bar graphs.
Class Discussion: Reports from groups. Analysis of graphs and data. Consideration of body measurements needed. Determination of sample and sample size. Decision made on what to include in the design.
Designs drawn. Selection of one is made.
Investigation of different units of measure, measuring instruments. Construction of instruments and testing their reliability.
Data Collection: Measurement of various body dimensions from selected sample.
Data Representation: Preparation of histograms, scatter graphs, slope diagrams.* Determination of the median and range of measurements.
Class Discussion: Reports from groups. Analysis of measurement data and graphs. Are our measurements accurate for our purpose? Do we need additional measurements? Does the design need modifications? Decision made on way to check proposed design for construction feasibility, proper fit, etc.
Design modifications
Data Collection: Additional measurements taken, if needed
Construction of prototype (full-scale model).
Class Discussion: Evaluation of prototype or model. Any changes needed? Re-examination of graphs to determine which sizes would be needed to fit everyone. Decision made on number of sizes and styles to make considering costs.

(Return to main flow chart.)

*Formerly called triangle diagram.

5. A COMPOSITE LOG*

This hypothetical account of a fourth-grade class describes many of the activities and discussions mentioned in the flow chart. The composite log shows only one of the many progressions of events that might develop as a class investigates the Designing for Human Proportions challenge. Documented events from actual classes are italized and set apart from the text.

Before starting the Designing for Human Proportions challenge, the class worked on the Classroom Management challenge. One outcome of their activities was the assignment of classroom jobs. One job was to maintain the class bulletin board. Over the past few weeks the several students who have charge of the board have been complaining because the board is so large and that there is not enough interesting material to put on it. This complaint is discussed during the next class session. Some students suggest adding more students to the committee. Another suggestion is to use only half of the board for display, setting aside the second half for class announcements, the daily menu, and articles or cartoons the children wish to share with others. The class likes this last idea and votes to adopt it.

Before the class can move to other concerns, one short boy comments that the bulletin board as it is presently hung is too high for him. Another student agrees and further adds that it is a nuisance to have to get a chair to stand on everytime something needs to be hung. Several children offer a quick solution--lower the board.

At this point the teacher takes the opportunity to introduce the challenge. On the board she writes "How can we change the bulletin board height so that everyone in the class can use it easily?"

Sixth graders at the Lyndale School in Minneapolis, Minnesota, investigated raising the frequently used mirrors outside their classroom. The students measured their heights and decided that the mirror top should be one-third higher than the average height in the class. The measurement data and the students' recommendation were presented to the principal. A few days later the mirrors were raised according to the students' recommendation. (See log by Barbara Dahlberg.)

A class debate between the short and the tall children evolves over the issue of how much to lower the board. The shorter children obviously want the board to be lowered more than the taller children think it should be. The class

*Written by USMES staff

decides then to measure everyone's height, but someone points out that it is really a person's reach that is important. Everyone agrees with this idea, and five children volunteer to measure everyone's maximum reach.

For the next few days the five children measure everyone's maximum reach. To do this, they have each child post, as high as they can without standing on tiptoe, a sheet of paper on the bulletin board. The distance between the thumbtack and the floor is then measured with the meter stick. Three members of the group collect classmates to be measured and check their names off the class list. One student measures, and the fifth student watches to make sure students do not stand on tiptoe and records the measurements.

To facilitate handling of the data, the group decides that the measurements should be rounded to the nearest centimeter. They agree that if the measurement falls between a centimeter mark and the half centimeter above this mark, the measurement should be rounded down to the centimeter mark below the measurement. If the measurement falls above the halfway mark, it should be rounded up to the next whole centimeter. If the measurement falls exactly halfway between two centimeter marks, the group decides that they will always round it down. Everyone is then measured.

The resulting measurement data is ordered in descending order and tallied. The data is shown below.

Maximum Reach (Rounded to nearest centimeter)	Number of Students
198	/
195	//
190	///
189	//
185	/
184	//
183	/
181	///
180	/
175	/
174	/
173	//

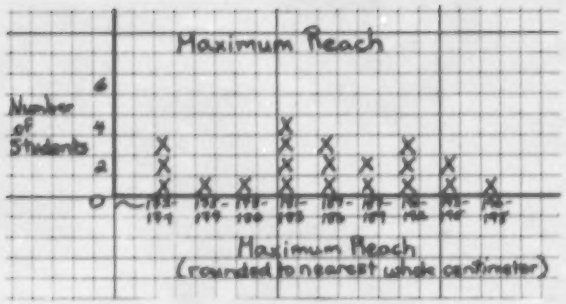


Figure B5-1

One student volunteers to make a graph so that the rest of the class can easily see how the measurements are distributed. Figure B5-1 shows this student's histogram. Another student who enjoys working with figures volunteers to calculate the mean value, which he finds to be 184.5 cm.

At the next class meeting the Measurement Group presents the data and the graph. The student who calculated the mean reports this value and comments on how long it took him to add and divide. The teacher points out that the group could have used the median which is much easier to find. She explains that the median is the middle measurement in their set of data so that half the measurements fall above and half fall below the median value. Using the histogram, the children count the total number of measurements and get twenty. They discover that there are really two middle measurements, the tenth and the eleventh. They notice that they cannot determine the exact median value from the histogram because the tenth and the eleventh measurements fall within the interval of 184 cm - 186 cm. They refer to the tallied data and discover that both the tenth and eleventh measurements are 184 cm. This, they then agree, is the median value.

Several children recommend that the top of the board be placed at the median height. If this occurred, then all the students will be able to use most of the board comfortably. The class checks this idea by subtracting the shortest reach (173 cm) from the suggested top height of the board (184 cm). They find that the two shorter students will not be able to use the top 11 cm of the bulletin board but will be able to reach the rest of it. One student further explains that those students who have reaches above the median can use the top half of the board while those with reaches less than the median can use the lower half of the board.

While working on another USMES challenge, students in one fourth/fifth-grade class worked on the problem of how high to post the school luncheon menu. The class decided that reading comfort was determined by one's eye level. They then agreed that since the menu was read by all the children in the school they would need to measure the height of everyone's eye level. Rather than measure everyone, however, they chose a sample size--they would measure every fifth student from

the alphabetical class list in every homeroom. The measurement data was ranked and the mean determined. The menu was then posted at the mean height. (See log by Marion Perkins.)

The class next discusses how to lower the board. Two students warn that they had better obtain permission from the principal first. These same two students are then assigned the task of making an appointment with the principal to explain the class project.

One week later two men come to the class to lower the board. The class stops all activity to oversee the change.

During the next session the teacher asks the class if there are other items that they use or wear that they can design or alter to be a better fit. Several items are suggested and listed on the chalkboard:

- height of storage shelves in the supplies closet
- height of pencil sharpener
- size of Design Lab smocks

One girl asks whether she can add "worktable" to the list since the classroom does not have one, and the class consents. As each suggestion is discussed, it becomes evident that the children feel that a worktable on which to do projects is needed most. A hand vote confirms this feeling.

The need for a workbench arose while working on the Weather Predictions challenge in one fourth-grade class in Cotuit, Massachusetts. Because the school had no Design Lab, the students had to use their desks for construction of weather instruments. This arrangement was found very unsatisfactory because the desks were too small and kept "jumping around" when the students hammered. The class discussed this problem, and a group of students volunteered to design and construct a table. (From log by Phyllis Viall Cooper.)

In further discussing the table the children raise three issues:

1. Where should the worktable be placed?

2. What should the table look like?

3. How high should the table be to accommodate everyone in the room?

After a thorough look around the room a space extending along the back classroom wall is decided as the best place for the worktable. Other locations are suggested, but the children note that these would require major rearrangement of the room.

The students next consider the table itself. Considerable time is spent discussing table designs before one frustrated student comments that such a decision could take all day. Someone suggests breaking into two groups, one to handle table design, called the Design Group, and the other to determine table height, called the Measurement Group. Everyone quickly agrees with this idea, and the children choose the problem on which they wish to work.

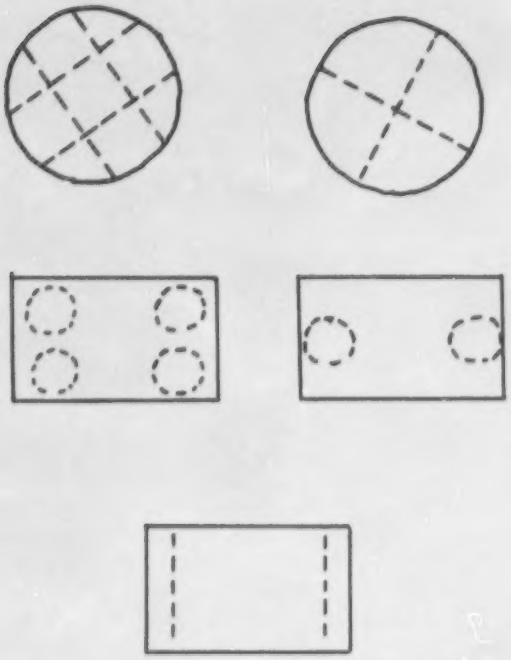


Figure B5-2

Design Group

The Design Group meets briefly and agrees that they should draw their designs individually. Later, the group can examine and critique each design and choose several to submit to the rest of the class. A vote is taken to reconvene the following day.

The next day those members who drew designs share them with the group. Each design is drawn on the chalkboard and explained. Most of the tables are very simple and are to be constructed from Tri-Wall. The main differences between the designs are the shape of the table surface (round vs. rectangular) and means of support. After thirty minutes all the designs have been shown. The group chooses five to submit to the rest of the class. Figure B5-2 shows the five chosen designs.

The Cotuit, Massachusetts, students decided to draw individual table designs. The best parts of each design were then selected to include in the final design. (From log by Phyllis Viall Cooper.)

Measurement Group

Eleven students interested in working on the table height problem gather at the front of the room. Someone opens the

discussion by commenting that the table height can probably be determined in the same manner that the class determined the height of the bulletin board. One student asks if the table will require chairs or benches. This question prompts another, "Do we want a worktable that requires us to stand or sit?" A quick vote among the group members reveals nine children who prefer to stand and two children who prefer to sit while doing projects. Because the group represents only half of the class, members of the other group are quickly polled. One student volunteers to take the survey and in a few minutes returns with the needed information: seven favor standing at a table, two favor sitting.

To determine table height for standing the group must decide what body measurement to obtain. They guess that one's height may be important but are not sure. They decide to put together a table-like structure to test different heights for comfort. A shelf from the closet is removed and placed between two desks. Two students stand on each side and pretend to do work. This level is found to be too low for these students. Books are placed under the shelf to raise it. Again the two students test the height. The height is still too low. The process continues until the students find a comfortable height. The students note that this height is approximately waist high. To be sure, other members of the group stand next to the table-like structure and pretend to do work. Although the height is a little high or low for some, there is general agreement that the distance between the waist and the floor is important for comfort for standing work.

The group proceeds to obtain the needed measurements. One boy questions how to determine where everyone's waist is since some boys' pant waistbands fall slightly below their waists. The problem is resolved when one boy suggests that the person who is being measured put a tape measure around his or her waist. The distance that is to be measured will be from the tape measure to the floor. Using meter sticks, members of the Measurement Group measure themselves first, then the Design Group members. One student records all the measurements. (They decide to use the same rounding off system that they used in measuring the maximum reaches.)

The measurement data is arranged in ascending order and tallied as shown on the next page:

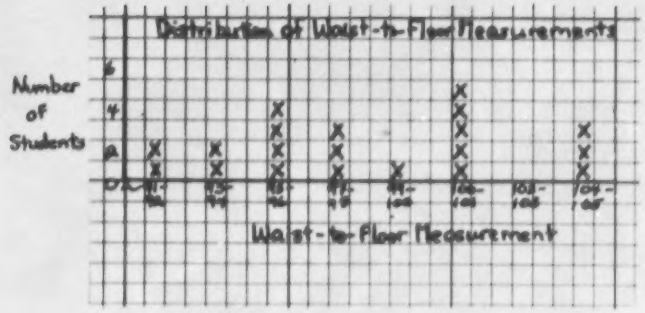


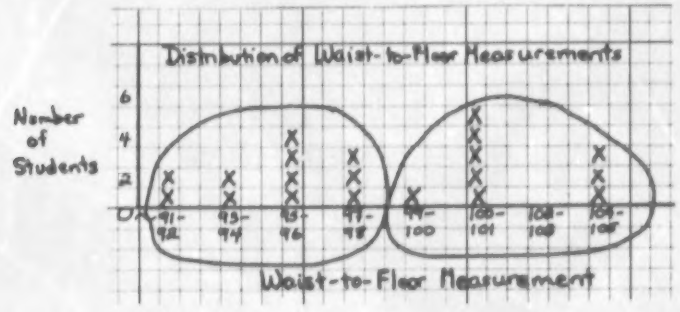
Figure B5-3

Waist-to-Floor Measurement (Rounded to Nearest Whole Centimeter)	Number of Children
92	II
93	II
96	IIII
97	I
98	II
99	I
101	++++
104	II
105	I

A histogram is made by one student. (see Figure B5-3) and is examined by the group.

While the groups are working, the class discussion times are devoted to reports of progress and discussions of any group problems. With group tasks completed the class spends time examining the data.

The Measurement Group briefly reviews their activities of the past several weeks. Since some of the students in the back row cannot clearly see the histogram, the graph is quickly drawn on the board. The group reports that the median waist-to-floor height is 98 cm and then recommends that the worktable be the median height. Immediately, the shorter students object, saying that this height would be too high for them. One girl suggests that tables of two different heights be made since the "X's" on the histogram seem to fall into two groups. To explain her point, she circles the two groups of "X's" on the graph, as shown below.



The class agrees and then decides that one table should be the median height of the lower group of measurements and the other table should be the median height of the upper group. They find that these two medians are 96 cm and 101 cm.

The sixth-grade students in the Minneapolis, Minnesota, class also designed and made aprons for children in the school. Body measurements critical for a good fit were determined to be chest width, waist-to-collarbone, waist circumference and waist-to-knee. Those measurements were obtained from a sample size of one class per every grade level. The data for each body measurement was graphed, and some were found to be correlated. Based on the analysis of their graphs, the class determined that five sizes of aprons would accommodate most of the students in the school. (See log by Barbara Dahlberg.)

One student then wonders whether there is enough room at the back of the classroom for two tables. Three students obtain meter sticks and measure the area. The area measures to be 274 cm by 152 cm. Several children comment that they do not think two tables can fit into this space. Others agree and wonder if the reading "corner" can be moved to another spot in the room to expand the area for the tables. Once again the students look around the room. After a few minor changes have been made, the reading corner is moved to a new location. The area designated for the worktables is remeasured. The new area measures 450 cm by 152 cm. The class feels that this is now more than enough room for two tables. Masking tape is put on the floor to delineate the table area.

The Design Group draws the five table designs on the board and explains each support design. A discussion ensues over the advantages and disadvantages of round and rectangular tables after the Design Group members admit that personal preference was the only reason for the choice of tabletop shapes.

Advocates for round tabletops claim that a more personal atmosphere is created with round tables and that more students can work at a round table than at a rectangular one. Those who prefer rectangular tabletops argue that the purpose of the table is to do work and that it is not meant to

be used as a discussion table. One student also points out that rectangular tabletops would waste less space than round tabletops because the area available for the two tables is rectangular.

The class then decides that they are most interested in the number of workers that can fit at each table shape. During the next several days this comparison is made between these two shapes.

The children decide to make the comparison on paper by drawing a scale layout. In their layout one millimeter represents one centimeter. The total work area is measured and divided in half. In each segment the maximum size tabletop shape (circle in one, rectangle in the other) is drawn, allowing adequate room for people to stand. The amount of area an individual needs in which to work comfortably is determined and represented in the form of a placemat. The number of placemats that fit on each tabletop shape is then determined. Figures B5-4 and B5-5 show the results of the children's comparisons.

The children note that although the same number of workers can work at each table, the work area on the round tabletop is used less efficiently, particularly near the center of the circle. The class concludes that since the rectangular tabletop provides more useful space, the two tables should be rectangular.

> *To determine the number of students that could work at their planned 3 ft. by 6 ft. workbench, the Cotuit, Massachusetts, students chalked an outline of the proposed tabletop on the floor. Different numbers of students stood around the outline and pretended to saw and hammer. The group decided that eight students could work comfortably at that size table although this number would vary with different activities. (From log by Phyllis Viall Cooper.)*

The class reexamines the five table designs and notes that they must now choose a table support design. The five choices are drawn on the board and discussed.

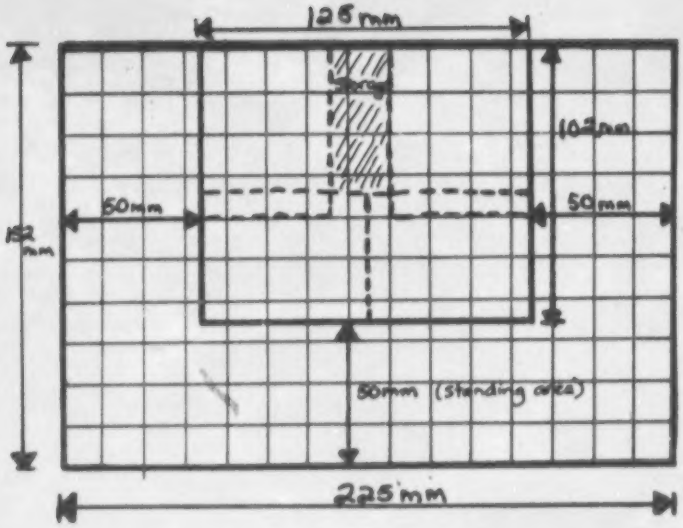


Figure B5-4

Workspace for One Individual

Scale: 1mm represents 1cm

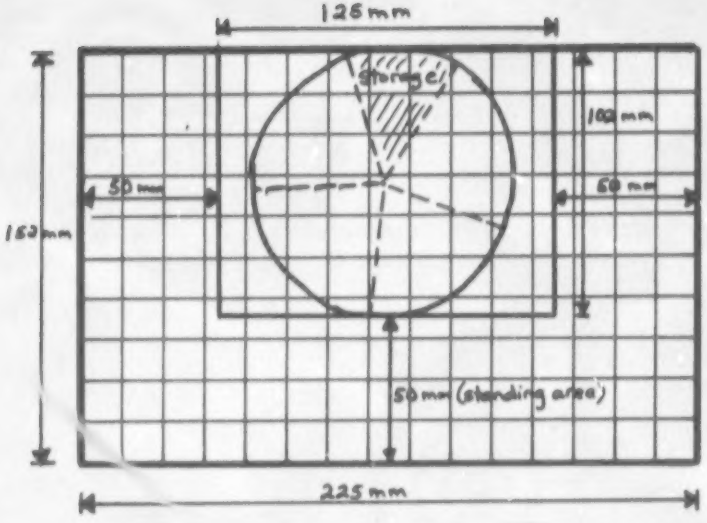
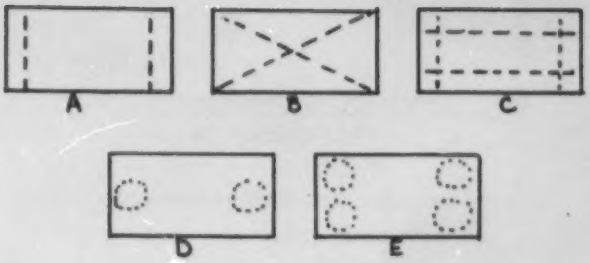


Figure B5-5

Workspace for One Individual

Scale: 1mm represents 1cm



The students speculate on which design would provide the most overall strength and stability (whether applied pressure in the middle of one table edge would make the whole table pitch in the direction of the pressure). Because there is no data on these two variables, the class appoints a group to make scale models of the five designs and to devise ways to compare overall strength and stability.

The group chooses the scale of two millimeters represents one centimeter. The table pieces are first drawn to scale on paper before being drawn on the single-layered cardboard. The cylinders are made from the single-layered cardboard, which is bent to form cylinder-type structures. To scale the cylinder thickness, the children glue a second cylinder inside each structure.

The group then performs the following tests:

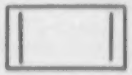
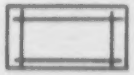
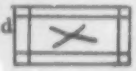
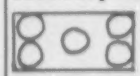
1. Tabletop strength in middle--place book on its side in the center of the table. Note whether tabletop sags. Use same book for each design.

2. Table stability--place capped jar filled with sand in middle of each table edge. Note whether table falls in the direction of the pressure.

3. Overall strength of support--continue stacking books (same books each time, e.g., student dictionaries) flat over whole tabletop until table collapses. Note the number of books each support design holds.

The group records the test results on a chart. They also record their recommendations for each design. The results of their efforts are shown on the next page.

Table Support Structure Tests

Design	Test for Tabletop Strength in Middle	Test for Stability	Test for Overall Strength, No. Books Held Up	Recommendations
A 	Collapsed	--	--	Eliminate Design
B	Didn't sag	Table fell in direction of pressure-long sides of table	Held 2 books	Provide support at two long edges, such as, (structures made from Tri-Wall)
C 	Didn't sag	All edges stable	Held 2 books	No alterations needed. Additional support may be provided under tabletop center, such as, (Tri-Wall slotted and put in form of "X") 
D	Sagged slightly	Table fell in direction of pressure-long sides of table	Held 1 book	Eliminate Design
E	Sagged slightly	All edges stable	Held 2 books	Provide Support under tabletop center, such as,  or

At the next class discussion the class hears the Scale Model Group's report and recommendations. The class considers construction aspects of the three remaining designs. Designs B and C (,) with their modifications are seen as not being any problem since the table components would all be made from Tri-Wall. Several students question Design E in terms of the feasibility of cutting to the proper heights the thick cylinders obtained from the local paper company. They remark that this task would be quite a hassle. The class agrees that they must now select either table support Design B or C with their respec-

tive corrective measures. A hand vote is taken and Design C is picked.

A few students ask who gets to make the table. At this point the class agrees to list the tasks on the board and then to form new groups. The class identifies the following new tasks:

1. Measure and draw table pieces
2. Cut table pieces; assemble tables
3. Paint tables

The class decides to form three groups to perform the above tasks. It is agreed that this plan will provide opportunity for more students to work on some aspect of the table construction.

The groups spend several weeks working. While one group works in the Design Lab, the other groups work on other classroom assignments. The table support pieces and the tabletops are measured and cut from Tri-Wall. The support pieces are then slotted and assembled. The tabletops are placed on top of the bases and glued, using the hot glue gun. To decide what color to paint the tables, the Paint Group checks with the Design Lab manager to determine what colors are available in fire-retardant paint. Of the choices available the group chooses yellow for the tabletops and green for the bases. They spend several days painting the two tables.

When the tables are completed, they are brought from the Design Lab to the classroom and placed in the appropriate area. The class marvels at how good they look. The following week several students comment how nice the tables look and how drab the rest of the classroom appears. Agreeing that something should be done, the class begins work on the Classroom Design Challenge.

6. QUESTIONS TO STIMULATE FURTHER INVESTIGATION AND ANALYSIS

- What are some of the problems you have in finding a comfortable chair and desk when you first come to school?
- What other items do not seem to fit properly or do not seem the proper height for you?

- What is the problem with the present height of the class bulletin board, drinking fountain, light switch? How high should the bulletin board be to accommodate everyone in the room? What measurements do we need to obtain?
- How can we make tables (desks, wristbands, etc.) or shirts (smocks, gloves, etc.) that will fit most children in the room?
- What measurements do we need to obtain?
- What is a good way to keep a record of our data?
- What is a good way to make a picture of our data?
- What do the graphs tell us?
- How does the design affect the measurements we need to consider?
- How can we find out which design people like best?
- How many children do we need to measure?
- Which children should we measure?
- How accurate do our measurements have to be?
- How many different sizes do we need to provide?
- How many variables do we need to consider in determining sizes (e.g., chest width and collarbone-to waist for smocks)?
- Which variables in a design are critical for fit and for comfort?
- How many of each size do we need to make?
- How can we find out?

C. Documentation

1. LOG ON DESIGNING FOR HUMAN PROPORTIONS

by Betty Gorham*
Whitehead Road School, Grade 3
Athens, Georgia
(October 1973-December 1973)

ABSTRACT

The Designing for Human Proportions challenge in this third-grade class evolved from several incidents where ill-fitting shoes created problems. The class decided to inform the local department store about the shoe sizes and preferences of the children in the school. Working two times a week on their challenge, the children traced around their feet, cut the tracing out, and measured it to the nearest inch to determine foot sizes. A pictograph and bar graph were made to show their data. The class also polled three other primary classes to determine shoe style preferences and shoe sizes. A letter was written to the local department store to share their findings.

The Designing for Human Proportions challenge evolved naturally in my third-grade class after several incidents occurred involving shoe comfort. One girl, who had forgotten to bring sneakers to school that day, had trouble participating in gym class because she could not run in her clogs. Another student complained that his feet hurt because his shoes fit too tightly. When he loosened the shoe laces to make them more comfortable, he tripped on the laces. A second girl, who had worn new shoes to school, complained of blisters on her heel.

The above incidents led to a discussion of what makes a shoe comfortable and what kind of shoe would be most suitable and comfortable for school wear. A hand vote showed that canvas shoes (alias, sneakers) were the favorite type of all-purpose shoe because they were the most comfortable.

I then asked the class what we would need to know if we wanted to inform a store about the shoe sizes and style preferences of the students in our school. The children recognized the need to measure everybody's feet to determine the various shoe sizes worn by students in the class.

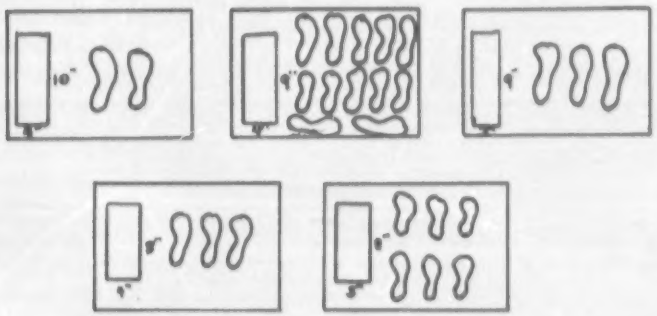
*Edited by USMES staff

We discussed how we could easily and accurately measure our feet. The class came up with the idea of first tracing around a foot and then measuring the tracing with a ruler. They felt that there would be less error in measurement using this method than trying to measure a foot directly.

The following day the children traced around one of each child's feet, leaving the shoe on. The tracings were cut out, and the length and the width of the pattern were measured to the nearest inch.

We tried to analyze our information afterwards. I asked the children what the most common shoe size was in our class. They could not answer me. They also could not tell me the number of different sizes there were in the class. I then took the opportunity to introduce graphs.

I placed large sheets of chart paper on the floor. In the upper left hand corner of each sheet, I placed a measured rectangle. There were five sizes of rectangles: 10 in. by 4 in., 9 in. by 4 in., 9 in. by 3 in., 8 in. by 4 in., and 8 in. by 3 in.* Each child looked for the rectangle that best fit his foot by placing his foot in each of the rectangles. When the appropriate rectangle was found, he placed his cutout tracing on that chart paper. Five charts were needed to accommodate all the sizes in our class. Sketches of the completed charts are shown below.



*The children could investigate whether these rectangles represented the sizes of shoes sold in stores. If other or different sizes of shoes were available, the children could make other rectangles to represent those sizes.--ED.

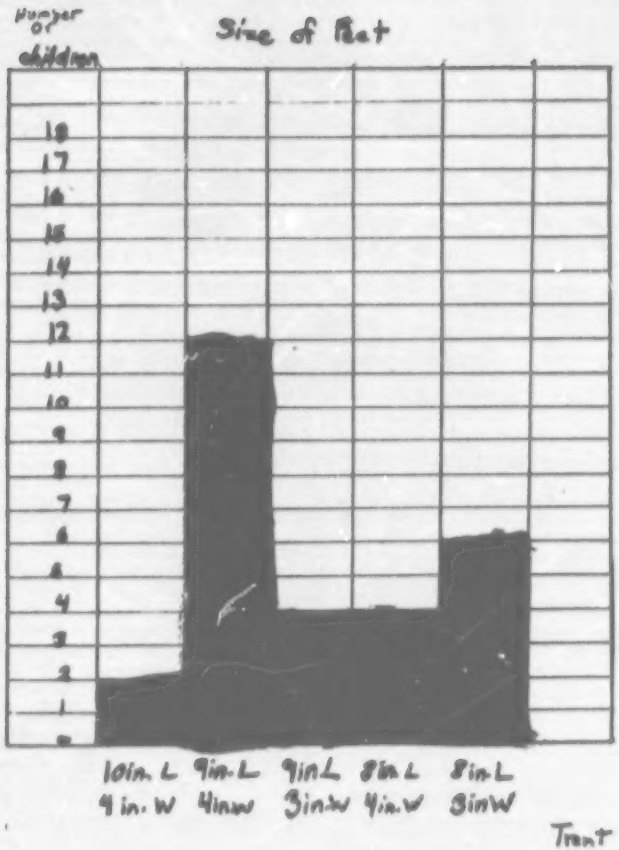


Figure C1-1

In examining the charts the children noted that the most prevalent rectangle size was 9 in. by 4 in. They also observed that all five sizes of rectangles were needed to accommodate everyone's foot size.

We then talked about how inconvenient it would be if we had to mail these large charts to the shoe stores. I introduced bar graphs, explaining that graphs were a picture of one's information. Using the "How To" Cards, "How to Make a Bar Graph Picture of Your Data," the children made their own graphs using the above data. Figure C1-1 shows one girl's bar graph.

The children next considered what shoe styles they preferred. Pictures of several shoe styles, such as boots, sneakers, oxfords, and high-heeled oxfords were brought in. We considered the good and bad points of each style. Several children felt that leather boots would be good for physical education classes because the high tops would provide good ankle support and prevent sand from getting into the boots when playing baseball outside. Others felt that the boots would scuff the floor in the gym and impede one's ability to run. The class thought that sneakers had many good features: they were washable, allowed flexible foot action, and, because they were tied on, did not fall off, even while playing kickball. They thought oxfords were nice looking but too hard to keep clean and at times were too stiff. The high-heeled oxfords were the least popular because the high heels made it practically impossible to walk.

I asked the class how we could find out which shoe style was most popular in our class for wearing to school. The children offered the following three suggestions:

1. Write down each style on a sheet of paper. Have each student write his name beside the style he liked the best.
2. Have each child write his name and preference on a sheet of paper and put the sheets in a box to be counted later.
3. Point to each shoe style and count the number of hand votes.

They accepted the last suggestion because they felt it would be quicker.

The results of the voting were as follows:

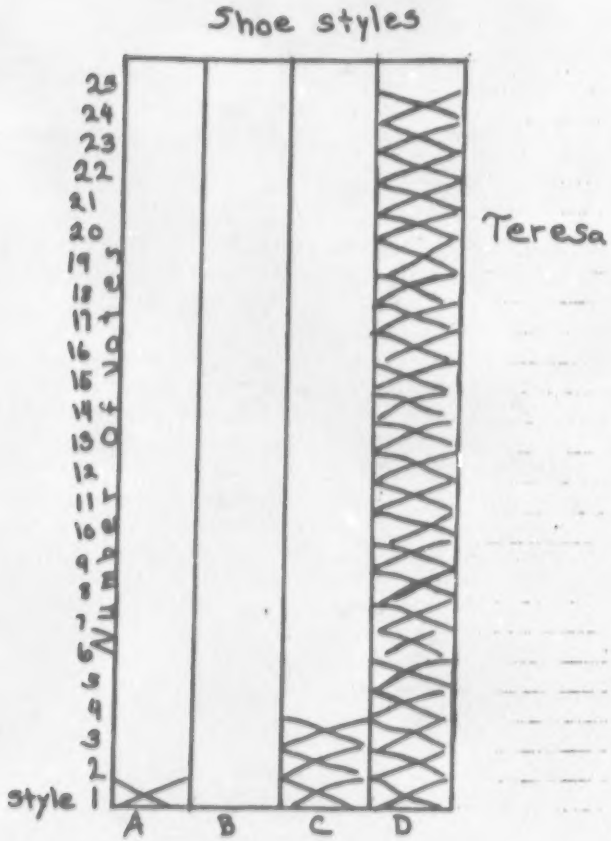


Figure C1-2

Shoe Style	No. of Votes
boots	3
regular oxfords	1
high-heeled oxfords	0
sneakers	24

The vote confirmed sneakers as the most popular style in the class. Bar graph tallies were made to show the resulting data. One child's bar graph tally is shown in Figure C1-2.

The next week we summarized our findings and preferences. Several children wondered whether other primary children in the school would also favor sneakers as a comfortable school shoe. The class decided to poll three other classes, two second grades and another third grade, to determine shoe preferences and the most common foot size.*

Groups were formed to make preparations for the poll. One group made a list of things that they had to tell or ask the other class teachers, such as explaining the purpose of the poll and asking when they could come to the class to administer the poll. A second group made a list of questions on shoe style preferences and shoe material preferences to be asked of the interviewed students. A third group made the rectangular foot measurers the class decided to use. The students cut the following sized rectangles: 10 in. by 4 in., 9 in. by 4 in., 9 in. by 3 in., 8 in. by 4 in., 8 in. by 3 in., 7 in. by 4 in., 7 in. by 3 in., and 6 in. by 3 in. A fourth group made folders to hold the collected data.

Arrangements were made with the other class teachers to administer the poll. We decided that the most efficient way to handle the polling was to divide the class into three groups, each group going to one class. Within each group individual tasks were assigned. The following were the tasks which were identified as being necessary: poll for style preference, measure feet and record data, make a bar graph of preferred styles, make a bar graph of foot sizes, make a graph showing the foot sizes in all four classes.

*The children might discuss whether it was necessary to measure every student. If they decide to measure only a sample of students in each class, then they might discuss how big the sample should be and how they should pick the sample.--ED.

The two bar graphs (data not available) showed--

1. that sneakers were the most popular shoes for school wear;
2. that the rectangle sizes, 9 in. by 4 in. and 8 in. by 3 in. were the most common sizes in each of the three classes;
3. that the range of foot sizes in all the classes was between 7 in. by 3 in. and 10 in. by 4 in.

The rectangular foot measurers were converted to shoe sizes after I obtained the information from the local shoe store. The two most common foot sizes (9 in. by 4 in. and 8 in. by 3 in.) were shoe sizes two and five. The class noted that the shoe size range for the second- and third-grade classes was size twelve to size eight (ten inches long). (Children's shoe sizes run from size one to size twelve and one-half. After size twelve and one-half the sequence repeats with misses and boys sizes, twelve and one-half, one, two, three, four, etc. Adult sizes begin with size four for girls and size six for boys.)

The children wrote letters to some of the local stores to share the information they had collected. The letter shown in Figure C1-3 was sent to Belk's Department Store.

From
Katie NOV 20, 1973

TO Belkes

I am doing a Survey
I am from Whitehead Road
Shool. Size2 and size5 are
the sizes that We wear
mast of all. We thought
You would like to know
They like Tennis-shoes the
Best! I like them
too. You have the
Best!

The End

Figure C1-3

2. LOG ON DESIGNING FOR HUMAN PROPORTIONS

by Barbara Dahlberg*
Lyndale School, Grade 6
Minneapolis, Minnesota
(November 1972-March 1973)

ABSTRACT

This sixth-grade class worked three times a week on problems involving human proportions. The class first expressed concern over the drinking fountain and mirror heights that were located near their room and were used frequently. The students decided what body measurements were important for use, measured themselves, graphed and analyzed the data, and made recommendations to the principal. To their delight, the mirror heights were changed according to their recommendations. They also learned that the drinking fountain height they had proposed closely matched the height of the new ones that were on order. A need for work aprons was then identified, and the children decided to tackle the challenge of making aprons for children in the school. Apron designs were drawn, body measurements critical for a good fit were identified, and students representing all grade levels were measured. The resulting measurement data was graphed and analyzed. The students also drew scatter diagrams of the various sets of measurements to determine possible correlations. Based on the analyses of the scatter diagrams, five apron sizes were recommended. Patterns were made and after comparative shopping for fabric, the class began apron production and activities of the Manufacturing challenge.

This year my sixth-grade class was placed in an area of the school that was originally designed for primary students. My students were very aware of classroom and school fixtures that were too small or too low for them. Complaints surfaced during a class discussion on the physical setup of the school one day. Many students pointed out that the classroom sinks, chalkboards, and drinking fountains were too low. (Desks and chairs had been exchanged for one of a more appropriate size.) One student observed that there were basically two sets of furniture in the library, the smaller and lighter set being for primary students. One boy summarized our discussion beautifully by stating that all these furniture dif-

*Edited by USMES staff

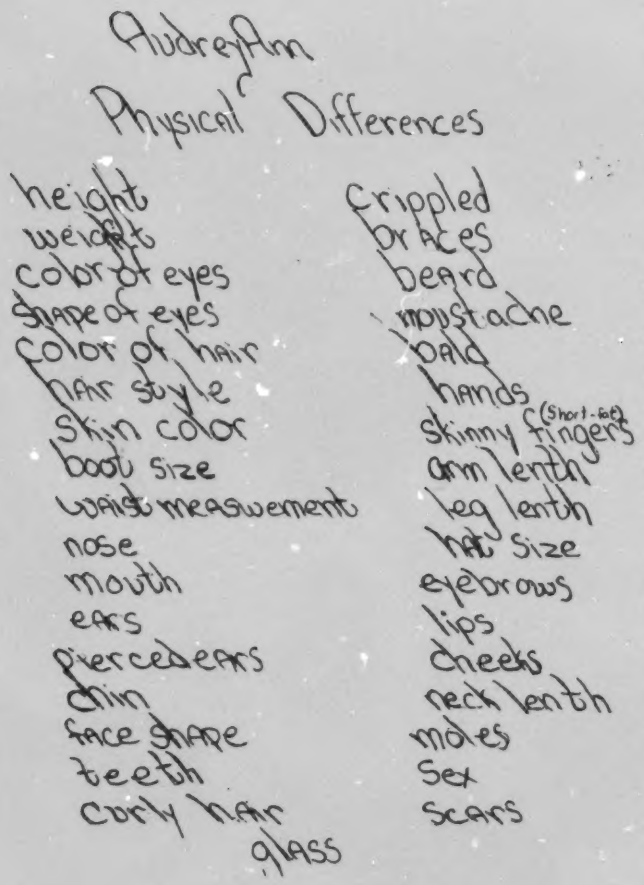


Figure C2-1

ferences were necessary because of the physical differences among students.

We proceeded to make note of some of the physical differences among people in general. At the end of the session a long list of physical characteristics (shown in Figure C2-1) had been compiled.

Since the height of the drinking fountains was a major source of complaints and new fountains were on order, we decided it would be fun to compare our recommended fountain height with the height of those on order. The class considered the body measurements that were important for comfort. These measurements were the height of a person and the distance from the floor to his waist, the latter measurement being the most critical for comfortable use. Upon one student's recommendation, the class decided to measure everyone's waist-to-floor distance and to determine the class average. Another student added that a footstool could be provided for the extra short students.

Working in small groups, the class measured everyone's waist-to-floor distance. The average waist-to-floor measurement for the girls was thirty-five inches. For the boys, the average measurement was thirty-four inches.

The class compared their height measurements with the present and the yet-to-arrive drinking fountain heights. The present fountains were found to be five inches below the girls' average waist-to-floor measurement. The ordered fountain heights were thirty-six inches high, one inch above the girls' average height. The class was quite pleased with this close similarity in results but a bit disappointed that it was too late to make changes.

The students next turned their attention to the 1½ ft. by 2 ft. mirrors just outside the classroom. The students were interested in the mirrors because they were used daily, and they felt that they could exert some influence in having the mirror heights changed. This time a person's total height was considered important. The class decided that the average class height should fall at two-thirds of the mirror height (two feet) or sixteen inches from the mirror bottom.

The class broke into groups to collect the measurement data on heights. The boys' average height was found to be fifty-nine inches (rounded to the nearest inch). The girls' average height was also found to be fifty-nine inches. The class then determined that the top of the mirrors should be at a height given by average height added to one-third of the mirror height (since the average height falls at two-thirds of the mirror height). Figure C2-2 shows one stu-

mirror 1½'x2'

Girls

Average height at ⅔ of mirror height

Top of mirror should be 59"+16=75" from the floor.*

60 ¼ in.
57 ½ in
58 ¼ in.
57 ½ in.
58 ½ in
61 ½ in.
58 in.
56 in.
59 ½ in.
60 in.
57 ½ in.
57 in.
57 ½ in.
62 in.
822*

14 | 822 — 58 12/14
70
122
112
10

Average = 59"

*Ed. Note: According to the text and the preceeding statement that "average height (in) at 2/3 of mirror height," the top of the mirror should be 59" + 8" = 67" from the floor, not at 75" as indicated.

Total = 821

Figure C2-2

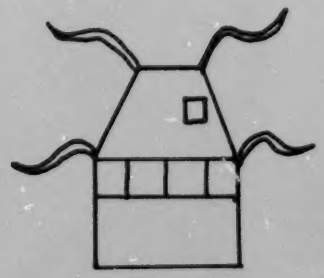


Figure C2-3

dent's calculations. Graphs of the students' heights were then made.

The following week a group of representatives from the class presented the data to the principal. They explained that the present mirror heights were too low for the majority of the members of their class. The graphs of the heights were shown along with their calculations. The principal was quite impressed with the class's work. Two days later a man came to our area to change the mirror heights. The class watched and was pleased.

In our next session, I told the students that the drinking fountain and mirror problems were relatively simple compared to those of designing clothes to accommodate a varied population. For example, we considered the body measurements that would be needed to make a pair of pants fit comfortably. The class felt that measurements, such as waist, calf, and thigh circumference, distance from waist to ankle, and distance from waist to knee, were important. They acquired an appreciation for clothing manufacturers when I asked them to consider the number of different combinations of the above measurements they would need to comfortably fit many different sizes of students.

To gain a greater appreciation of manufacturing items to accommodate a varied population, I asked the class if there were some piece of clothing that we could make for ourselves or the students in the school. The students came up with several possibilities, such as socks, belts, scarves, mittens, and work aprons. The class voted and selected work aprons.

At first the class decided that the first task they needed to do was to collect body measurements. However, they soon realized that they did not know what to measure. Upon the recommendation of one student, the students decided to agree on an apron design first. From the design they could determine the necessary body measurements.

Several apron designs were drawn and submitted to a committee that was set up to evaluate the various designs. The committee selected four designs for the class to consider. During the class discussion each creator drew and explained his design. Before a final vote was taken, the committee reminded the class that the vote was not a popularity contest: they were to select the one design that could be made for all the students in the class or school. The winning design is shown in Figure C2-3.

At this point one student asked if the class could sell the aprons to other students in the school and keep the

grade____age____sex____

_____ chest width
_____ waist to collarbone
_____ waist
_____ knee to waist

Figure C2-4

Knee to Waist
measured in inches

10		20	𝍸 𝍸 𝍸 I
10½		20½	III
11		21	𝍸 𝍸 III
11½		21½	III
12		22	III
12½		22½	I
13	𝍸	23	
13½	II	23½	
14	𝍸 𝍸	24	
14½	II	24½	
15	𝍸 IIII	25	
15½	I	25½	
16	𝍸 𝍸 𝍸 III		
16½	𝍸		
17	𝍸 𝍸 𝍸 IIII		
17½	I		
18	𝍸 𝍸 𝍸		
18½	𝍸 I		
19	𝍸 𝍸 𝍸 𝍸		
19½	IIII		

Robin Deemar

Figure C2-5

money. This idea was agreeable to both the principal and me. The prospect of making money excited the whole class.

The class identified the following body measurements that were considered critical for a good fit:

1. length from collarbone to waist
2. chest width
3. waist
4. length from knees to waist
5. hip width
6. length of ties at waist
7. length of ties at neck

One student suggested that we measure every student in the school to determine the number of sizes we would need to make. Another student quickly reminded her that there were 800 students in the school. It was agreed then that they would measure one class per grade level.

A chart form on which to record each child's measurements was made by a group and submitted for class consideration. After discussion the class agreed that there were essentially four body measurements that were critical for a good apron fit. These four measurements appeared on the final chart form that is shown in Figure C2-4.

The class divided into small groups to collect the measurement data from the various classes. A total of 180 students were measured.

To organize and analyze the measurement data, the class agreed to form groups; however, once the groups were formed, the students were unsure of the best ways to organize the information. Someone suggested tallying the number of students with various chest widths, waist circumferences, and so forth, and then making bar graphs later. The group agreed that this idea was good, and each group took one body part to tally all the measurements. Figure C2-5 shows one group's tally.

While the above small groups organized the data, the rest of the class compiled a list of questions that they hoped the graphs would answer.

1. What are the highest and lowest measurements?
2. What is the most frequent measurement?
3. How many sizes would be needed to accommodate all measurements?
4. Is there a pattern formed by the measurements?
5. Is more information needed?

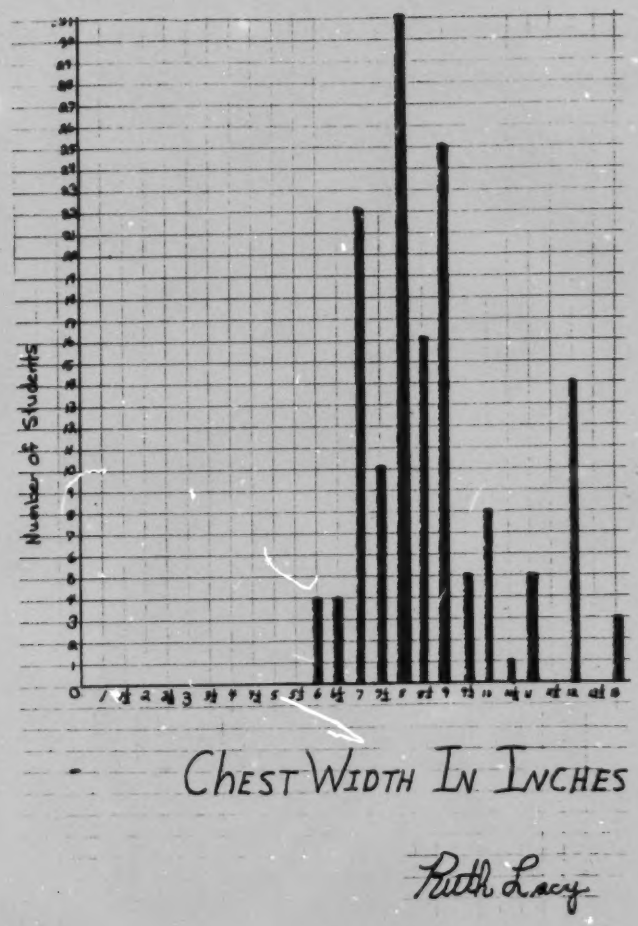


Figure C2-6

For the next four sessions, the groups gave their reports. The Chest Width Group explained their graph (shown in Figure C2-6) as follows:*

1. The range was from 6 in. to 13 in.
2. The most frequent measurement was 8 in.
3. Two-thirds of all students measured had chest widths of 7 in. to 9 in.
4. Three sizes were recommended as follows:

   small: 7 in. (for range 6 in.-7½ in.)
   medium: 8½ in. (for range 8 in.-9½ in.)
   large: 11½ in. (for range 10 in.-13 in.)

5. A comparison of chest width vs. distance from collarbone to waist was recommended.

The class agreed with their findings, and no one questioned their recommended size categories of small, medium, and large. When I asked them to explain how they arrived at these sizes, they told me that based on the distribution of the measurements, these sizes seemed likely to accommodate most of the population.**

The Waist-to-Collarbone Group presented their graph and explanation as follows:

1. The range was from 8 in. to 18½ in.
2. There were two most frequent measurements, 12 in. and 13 in.
3. Most measurements fell in the middle range; there were few at either extremes.

*The children might discuss the fact that the bars at each one-half mark (e.g., 6½, 7½) are consistently shorter. They might decide to make a one-inch range for each bar rather than a half-inch range.--ED.

**The children might be asked to figure out the number and amount of the misfits with each of these three sizes. A misfit might be defined as one inch (or more) too large or too small. Histograms might be constructed on a peg-board; blocks placed on pegs in appropriate holes would represent misfits. The children could then try to reduce the number of misfits by changing the three sizes.--ED.

4. If three sizes of aprons were offered, the following sizes would be recommended:

   small: 9½ in. (for range 8 in.-11 in.)
   medium: 13 in. (for range 11½ in.-14½ in.)
   large: 16 in. (for range 15 in.-18½ in.)

5. If four sizes of aprons were offered, the following sizes would be recommended:

   Size A: 9 in. (for range 8 in.-10 in.)
   Size B: 12 in. (for range 10½ in.-13 in.)
   Size C: 14½ in. (for range 13½ in.-15½ in.)
   Size D: 17 in. (for range 16 in.-18½ in.)

The Waist-to-Collarbone Group highly recommended offering four sizes of aprons to insure a better fit. The class generally agreed with this recommendation, but they wanted to wait until the other groups had presented their data before deciding.

The Waist Group explained their graph as follows:

1. The range is from 21 in. to 37 in.
2. One-half of the waist measurements fall between 23 in. to 25 in.
3. There is a greater range of waist measurements than is found in other measurements reported so far.
4. If three sizes of aprons were offered, the following sizes would be recommended:

   small: 23 in. (for range 21 in.-24 in.)
   medium: 26 in. (for range 24½ in.-28 in.)
   large: 31 in. (for range 28½ in.-37 in.)

5. If four sizes of aprons were offered, the following sizes would be recommended:

   Size A: 22 in. (for range 21 in.-23 in.)
   Size B: 25 in. (for range 24 in.-26 in.)
   Size C: 28 in. (for range 27 in.-30 in.)
   Size D: 33 in. (for range 31 in.-37 in.)

The Waist Group then pointed out that the waist measurement was probably not as critical for a good fit as were the other measurements due to the design of our apron. Indivi-

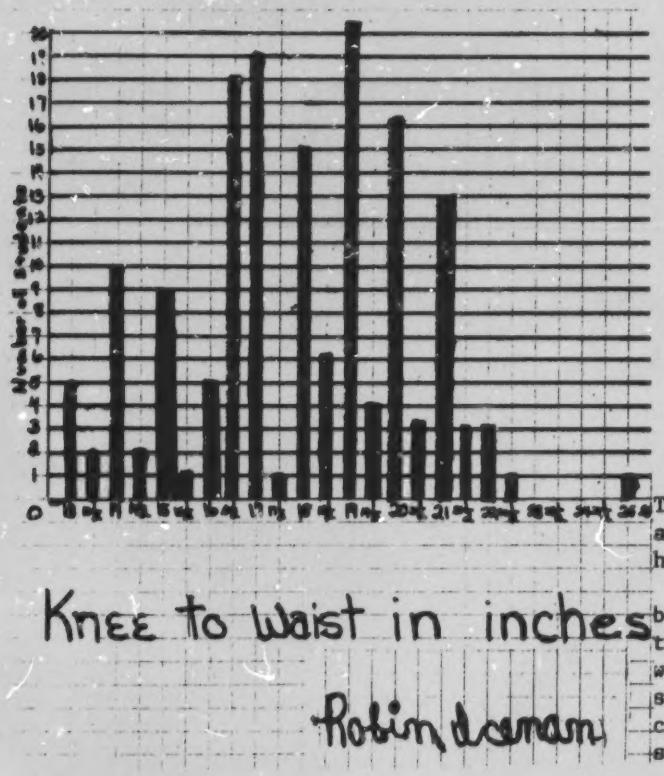


Figure C2-7

duals could adjust the waist size by adjusting the tie-strings.

Finally, the Knee-to-Waist Group presented their graph (shown in Figure C2-7) and explanation as follows:

1. The range was from 13 in. to 25 in.
2. The distribution of the measurements is spread out.
3. If three sizes of aprons were offered, the following sizes would be recommended:

   small: 15½ in. (for range 13 in.-15½ in.)
   medium: 19 in. (for range 16 in.-19 in.)
   large: 23 in. (for range 19½ in.-25 in.)

4. If four sizes of aprons were offered, the following sizes would be recommended:

   Size A: 15 in. (for range 13 in.-15 in.)
   Size B: 17 in. (for range 15½ in.-17 in.)
   Size C: 20 in. (for range 17½ in.-20 in.)
   Size D: 23 in. (for range 20½ in.-23 in.)

This group then concluded that it would be better if an apron were too long than too short because a person could hem the apron to any desired length.

After the groups had reported, the class was anxious to begin making the apron patterns. However, one girl dampened this enthusiasm when she asked how we knew the various parts would fit together properly; that is, would a customer necessarily take a medium size in all four measurements? The class groaned as they realized that some comparisons of measurements had to be done.*

Groups were then established to make scatter graphs comparing the following measurements:

1. collarbone-to-waist vs. chest width
2. collarbone-to-waist vs. waist-to-knee
3. waist vs. waist-to-knee

*An interesting mathematical analysis would be the number of separate sizes required if all the above choices were needed independently. If there were only three sizes in each of the four categories, then there would be 3x3x3x3 or 3^4 = 81 separate sizes.--ED.

Again, each group made the graph and explained it to the rest of the class.

Comparison of Collarbone-To-Waist with Chest Width

This scatter graph (see Figure C2-8) showed definitely a relationship between these two characteristics: as chest width increased, the distance from collarbone to waist increased. The students grouped their dots on their graph into five groups. They then recommended the following measurements for five sizes:

	Sizes				
	A	B	C	D	E
Chest width	7 in.	8 in.	8 in.	9 in.	11 in.
Collarbone-to-waist	9 in.	11 in.	13 in.	15 in.	17 in.

Comparison of Waist with Waist-to-Knee

The group comparing these two characteristics found the scatter graph very confusing because the points were scattered all over the graph. Their recommendation was that the graph have no part in determining the apron sizes since waist measurement on an apron can be varied to suit the wearer by adjusting the tie-strings.

Comparison of Collarbone-to-Waist with Waist-to-Knee

The scatter graph (Figure C2-9) of these two characteristics showed only a slight relation, but there was still a general increase in the distance from the waist to the knee as the distance from the waist to collarbone increased. Since the class agreed that the distance from waist to collarbone was more crucial than the distance from waist to knee, the group recommended the following measurements for five sizes:

	Sizes				
	A	B	C	D	E
Collarbone-to-Waist	9 in.	11 in.	13 in.	15 in.	17 in.
Waist-to-Knee	18 in.	19 in.	19 in.	20 in.	21 in.

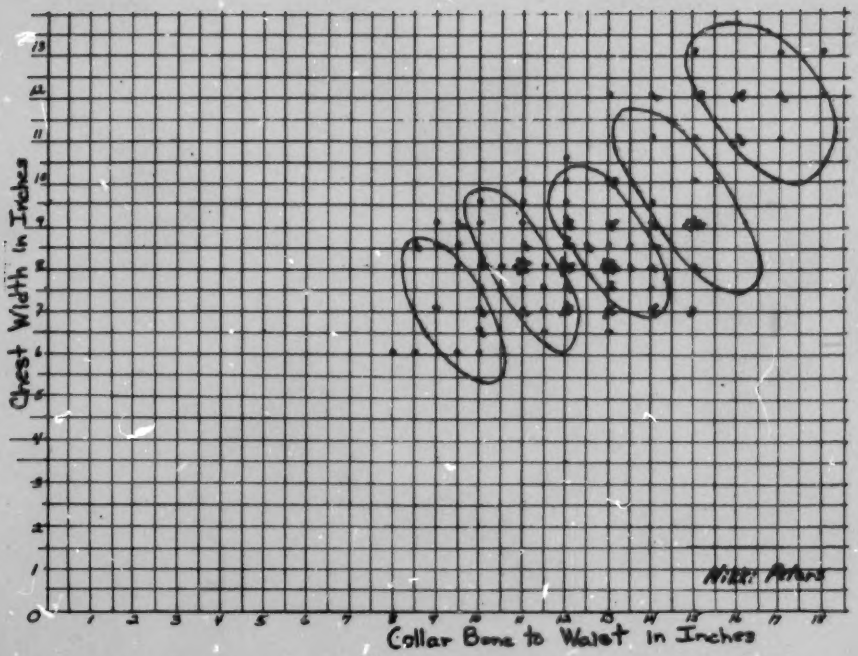


Figure C2-8

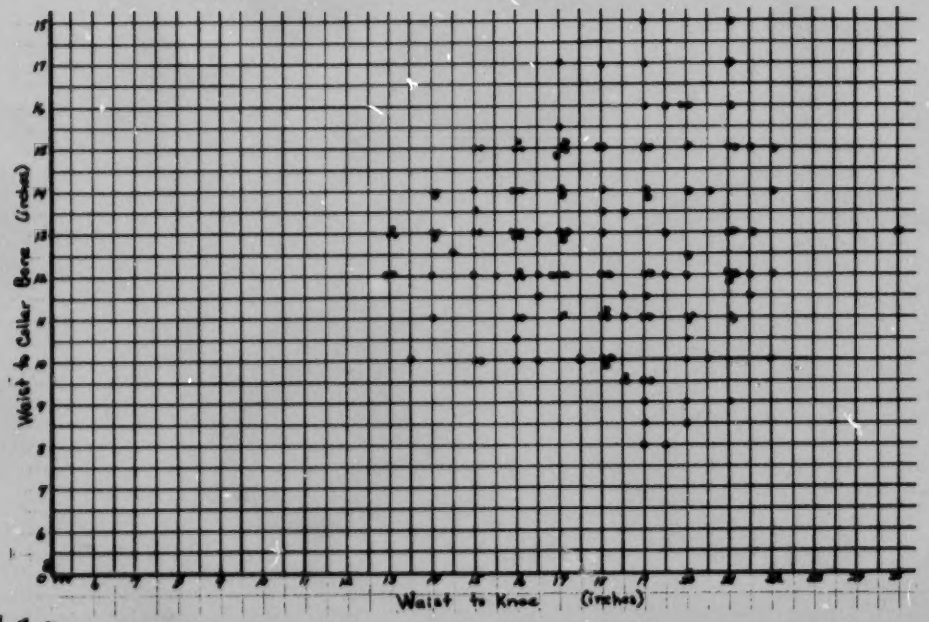


Figure C2-9

The next day the class indicated that they were satisfied with all the data collected. They were particularly eager to establish the sizes before Christmas vacation. All the graphs were posted in the front of the room so that everyone could see them. We decided to use the sizes recommended by the Collarbone-to-Waist vs. Chest Width Group. To these measurements we added the measurements for the length from waist to knee recommended by the Collarbone-to-Waist vs. Waist-to-Knee Group. Using the results of the waist vs. Waist-to-Knee Graph, we concluded that the waist varied throughout the rest of the measurements. Therefore, the class decided to make the width of the aprons twenty to twenty-three inches with long tie strings to accommodate all sizes of waists.

From the graphs the class established the following five sizes and measurements:

	Sizes				
	A	B	C	D	E
Chest Width	7 in.	8 in.	8 in.	9 in.	11 in.
Collarbone to Waist	9 in.	11 in.	13 in.	15 in.	17 in.
Waist to Knee	18 in.	19 in.	19 in.	20 in.	21 in.
Width of Apron	20 in.	21 in.	21 in.	22 in.	23 in.

One student commented that sizes B and C could be combined since they varied only at one point, but the class disagreed because that was the measurement they considered most crucial.*

After Christmas vacation the class began apron production and consequently became involved with the Manufacturing challenge. The five patterns were drawn on paper and cut out. Five students accompanied me to the department store to select and purchase the fabric. Fabric selection was based on price and whether the material felt "sturdy."

Initially the students worked in pairs pinning and cutting the aprons. Then, each student sewed his apron to

*The children could verify this premise by checking the number of misfits that would result from this combination of sizes. (See second footnote on page 50.)--ED.

completion. As time elapsed, however, the need for a more efficient production means was seen. Stations were set up for pinning and cutting out the patterns, pinning the apron edges, and sewing the apron. Later, a quality control group was established after several students noticed that the apron pockets had a tendency to come loose at the top. This change not only made things more organized but also motivated students to help each other.

As more aprons were finished, many students began making plans for the sale. One group used the fabric scraps to make small aprons to put on posters advertising the apron sale. A financial group set the price of the aprons. Another group set up the store area. A work schedule was made, and one boy was given the responsibility of counting the money after each sale day.

The class sold $126.00 worth of aprons. After subtracting their expenses, they found that their profit was $44.36. With this profit the students donated $30.00 to the school library, spent $4.76 on gifts for people who had loaned them the sewing machines, and spent $9.60 on a party for themselves.

3. MINI-LOG ON DESIGNING FOR HUMAN PROPORTIONS
Posting the Luncheon Menu

by Marion Perkins*
Whitehead Road School, Grades 4-5
Athens, Georgia
(October 1975-November 1975)

ABSTRACT

This fourth/fifth-grade class worked twice a week on the challenge of finding a suitable height to post the weekly luncheon menu. After a discussion the class agreed that eye level was important for reading comfort. Rather than measure the eye level of every student in the school, the class decided to measure every fifth student on the alphabetical class list in each homeroom. Grades kindergarten through sixth were included in this sample. The measurement data was then arranged in ascending order. The mean, median, and mode were determined. The menu was then posted at a height midway between the mean and mode heights.

Our Designing for Human Proportions challenge evolved from work on the Eating in School challenge. We were trying to make eating in our school lunchroom a more enjoyable experience. The class had several ideas for improving the lunch hour, one of which was to post a menu of the lunches to be served that week. The school dietician was invited to speak to the class on this idea as well as other luncheon concerns. Several days after this meeting the class was given permission to post a weekly menu. Naturally, the class was thrilled.

Little discussion was needed to decide where to post the menu. The class was in total agreement that the menu should be hung just inside the entrance to the lunchroom since this was where the lunch line slowed down and students would have plenty of time to read it.

The class next considered how high the menu should be placed. Someone quickly suggested a height of seven feet. We measured this height on the wall. It was obviously too high. The second suggested height was two feet. Again, measurement showed the error in this guess.

One child suggested posting the menu at eye level. A

*Edited by USMES staff

very animated discussion followed on what eye level was. It was finally decided that the height of everyone's eye level was not the same. Remembering some past work in math class, someone suggested that we measure everyone in the school for eye level and then find the average height.

This suggestion prompted a skill session on the mean, the median, and the mode. After this session the class decided that we should post the menu at the height of the mode rather than the mean height.

During the next session, plans were made to measure the eye level height of every student in the school. I asked the class whether they thought it was necessary to measure everyone. Several students suggested that we measure only a few students from each class, and others agreed that this plan was more practical.

We talked about ways we could choose a sample from the total school population. One student thought we should pick the first student in each row in every class. Another suggested just picking at random four or five students from each class. We finally agreed to measure every fifth student from the alphabetical class list in each homeroom.

Several students questioned whether we should include the kindergartners and first graders in our measuring sample since these children could not read. After some debate the class decided to include them, the rationale being that most first graders would be reading soon. Also, if they put food pictures on the menu, the menu would serve as an excellent reading aid.

The students used the measuring stick on the weight scale. The student sample in our class was measured first. Each student stood erectly on the scale. One student read the height of the eye level measurement and rounded it to the nearest inch. As he called out the height, another student recorded it.

No sooner had the first few students been measured than the question arose as to whether we should measure with or without shoes. It was decided that shoes should be left on since students would be wearing them when reading the menu.

As the above measuring took place, various students went to other homerooms, explained our project to the teachers, and brought back the sample students. At the end of the second day, the class had measured ninety-one students.

The eye level heights were arranged in ascending order. The data is shown below.*

42	48	50	51	54	58
	48	50	51	54	58
43	48	50	51		58
	48	50	51	55	
44	48	50		55	59
44	48	50	52	55	59
44	48	50	52	55	
	48	50	52	55	60
45	48	50	52		
	48	50	52	56	
46		50		56	
46	49	50	53	56	
46	49			56	
46	49	51	54	56	
	49	51	54		
47	49	51	54	57	
47	49	51	54	57	
47	49	51	54	57	
	49	51	54	57	
	49	51	54	57	

The students easily determined the median, fifty-one inches and the mode, fifty inches.

However, finding the mean posed a more difficult problem. No one was anxious to find the sum of ninety-one addends. We talked about possible ways of finding this sum. Then I let the class work in small groups to find the sum. The successful groups used a variety of methods of adding. One group added to find sub-totals of several addends and then added the sub-totals to obtain the grand total. Another group determined sub-totals by multiplying the height measurement by the number of children whose eye level was this measurement. The final step was then to divide the total by ninety-one which we did together. The mean was fifty-one inches.

We then returned to our original problem of how high to post the menu. Recalling that the class had decided to post it at the mode height, I asked the class whether they still wished to do this. Some discussion followed as to which

*To facilitate data analysis, the class could tally their data on a histogram.--ED.

height would be best. They finally agreed to post it midway between the mean and mode heights of fifty and one-half inches. The menu is now prominently displayed at that height in the lunchroom.

4. MINI-LOG ON DESIGNING FOR HUMAN PROPORTIONS

Height-Weight Scatter Graph

by Barbara Dahlberg*
Monte Vista School, Grade 5
Monterey, California
(November 1971)

ABSTRACT

This fifth-grade class worked twice a week comparing the heights and weights of students in kindergarten through sixth grades. Students from the various grade levels were measured by the class, and the data was plotted on a scatter diagram. In examining the graph, the class noted that the majority of points clustered together in an upward curve. The students suggested that they could probably predict a person's weight knowing his height. This idea was tested on a fourth-grade class. The class also compared furniture and room fixture heights in the different grade levels.

The class had been working on the Describing People challenge. The students noted physical characteristics that were similar or different among themselves. Soon they became interested in finding out the differences in growth rate, particularly height and weight, from kindergartners through sixth graders. The class decided that students representing all the grade levels should be measured for height and weight.

To carry out the measuring in an orderly manner the class identified and assigned tasks. It was voted that the students from the other classes should come to our room. Teams for measuring height and weight were formed. Another group was responsible for organizing the students once they arrived in our room and lining them up. Several students were responsible for escorting the visitors back to their classrooms when measurements had been taken.

When the measuring had been completed, we discussed what to do with the height and weight data. The class wanted to put each student's height and weight on the same graph but were unsure how to proceed. At this time we had a skill session on scatter diagrams. Together we plotted every student's height and weight measurements.

The class observed that the majority of the plotted points on the graph clustered together in an upward curve

*Edited by USMES staff

Figure C4-1

(graph not available). The students then suggested that they could probably predict someone's weight from knowing his height. We decided that it would be fun to test our idea.

A fourth-grade class that had not been involved with our previous measuring was invited to come to our class. Each student measured one fourth grader's height and then predicted his weight using our scatter diagram. The fourth grader's actual weight was then measured and recorded. The difference between the actual weight and the estimated weight was calculated for each student. The data is shown below.

Predicting Weight from Knowing Height
Fourth Grade Students

Height (in inches)	Estimated Weight (in pounds)	Actual Weight (in pounds)	Difference Between Predicted and Actual Weight
58	81	100	19
52	77	83	6
51	58	63	5
54	60	70	10
55	63	69	6
58	69	91	22
55	70	69	1
53	69	70	1
53	69	73	4
55	60	71	11
51	63	74	11
54	81	77	4
51	63	61	2
49	58	69	11
51	58	61	3
53	69	67	2
52	60	69	9
55	69	70	1
54	69	76	7
54	81	78	3
52	57	68	11
55	83	83	0
53	72	75	3
54	78	67	11

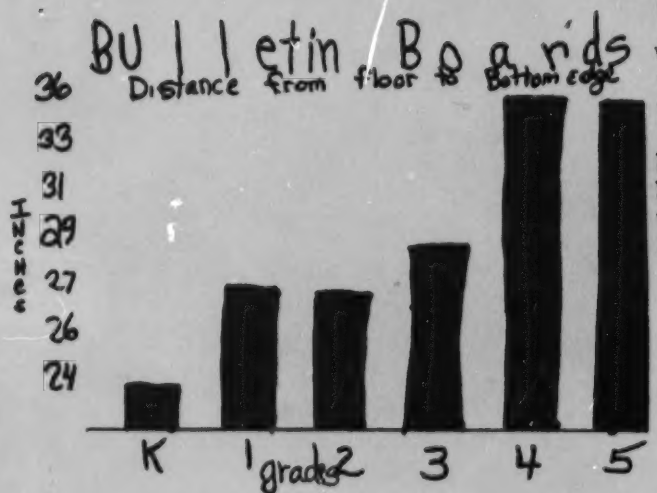


Figure C4-2

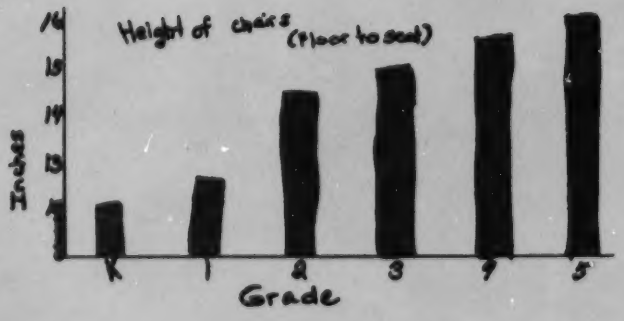


Figure C4-3

Some students then made a bar graph showing the number of students whose weight had been predicted within six pounds of their actual weight. Figure C4-1 shows one student's graph.

The class noted that at least half of the class predicted within six pounds of the actual weight. Someone suggested that weight guessers at a fair probably used a chart similar to our scatter diagram to predict weights.

The class further investigated different rates of growth by measuring and comparing furniture and room fixture heights in the different grade levels. The class measured various classroom items at each level, some of which are listed below.

chairs (from seat to floor*)
tables (table height)
desks (desk height)
counters (counter height)
doorknobs (height from floor)
pencil sharpener (height from floor)
bulletin boards (from bottom edge of board to floor)
windows (window height)
light switch (height from floor)

Bar graphs were made for each classroom item measured. Figures C4-2 and C4-3 show two students' graphs.

One result of their exploration was the discovery that their present classroom puppet theater was too small. One more appropriate to their size was then designed and constructed.

*Many classrooms contain a variety of sizes of chairs. A good activity might be to measure all the chairs, make a bar graph showing the number of chairs of each size, and then compare this data with the graph of children's heights (or distance from knee to foot). Perhaps a better distribution of chairs could be arranged in the school.--ED.

D. References

1. LIST OF "HOW TO" CARDS

Below are listed the current "How To" Card titles that students working on the Designing for Human Proportions challenge might find useful. A complete listing of both the "How To" Cards and the Design Lab "How To" Cards is contained in the USMES Guide. In addition, the Design Lab Manual contains the list of Design Lab "How To" Cards.

GRAPHING

GR 1 How to Make a Bar Graph Picture of Your Data
GR 2 How to Show the Differences in Many Measurements or Counts of the Same Thing by Making a Histogram
GR 3 How to Make a Line Graph Picture of Your Data
GR 6 How to Make Predictions by Using a Scatter Graph
GR 7 How to Show Several Sets of Data on One Graph

MEASUREMENT

M 9 How to Make a Conversion Graph to Use in Changing Measurements from One Unit to Another Unit
M 10 How to Use a Conversion Graph to Change *Any* Measurement in One Unit to Another Unit

PROBABILITY AND STATISTICS

PS 2 How to Record Data by Tallying
PS 3 How to Describe Your Set of Data by Finding the Average
PS 4 How to Describe Your Set of Data by Using the Middle Piece (Median)
PS 5 How to Find the Median of a Set of Data from a Histogram

RATIOS, PROPORTIONS, AND SCALING

R 1 How to Compare Fractions or Ratios by Making a Triangle Diagram*
R 2 How to Make a Drawing to Scale
R 3 How to Make Scale Drawings Bigger or Smaller

New titles to be added in 1976:

How to Round Off Data
How to Compare Two Sets of Data by Making a Q-Q Graph
How to Design and Analyze a Survey
How to Choose a Sample

*Presently called Slope Diagram

How to Compare Two Sets of Data by Using Interquartile Ranges
How to Make and Use a Cumulative Distribution Graph
How to Design an Experiment

A cartoon-style set of "How To" Cards for primary grades is being developed from the present complete set. In most cases titles are different and contents have been rearranged among the various titles. It is planned that this additional set will be available early in 1977.

2. LIST OF BACKGROUND PAPERS

As students work on USMES challenges, teachers may need background information that is not readily accessible elsewhere. The Background Papers fulfill this need and often include descriptions of activities and investigations that students might carry out.

Below are listed titles of current Background Papers that teachers may find pertinent to Designing for Human Proportions. The papers are grouped in the categories shown, but in some cases the categories overlap. For example, some papers about graphing also deal with probability and statistics.

The Background Papers are being revised, reorganized, and rewritten. As a result, many of the titles will change.

DESIGN PROBLEMS

DP13 People and Space by Gorman Gilbert

GRAPHING

GR 2 Notes on Data Handling by Percy Pierre
GR 3 Using Graphs to Understand Data by Earle Lomon
GR 4 Representing Several Sets of Data on One Graph by Betty Beck
GR 6 Using Scatter Graphs to Spot Trends by Earle Lomon
GR 7 Data Gathering and Generating Graphs at the Same Time (or Stack 'Em and Graph 'Em at One Fell Swoop!) by Edward Liddle

GROUP DYNAMICS

GD 2 A Voting Procedure Comparison That May Arise in USMES Activities by Earle Lomon

MEASUREMENT

M 1 Gulliver's Travels Activity by Abraham Flexer
M 3 Determining the Best Instrument to Use for a Certain Measurement by USMES Staff

PROBABILITY AND STATISTICS

PS 4 Design of Surveys and Samples by Susan J. Devlin and Anne E. Freeny
PS 5 Examining One and Two Sets of Data Part I: A General Strategy and One-Sample Methods by Lorraine Denby and James Landwehr
PS 6 Examining One and Two Sets of Data Part II: A Graphical Method for Comparing Two Samples by Lorraine Denby and James Landwehr

RATIOS, PROPORTIONS, AND SCALING

R 1 Graphic Comparison of Fractions by Merrill Goldberg
R 2 Geometric Comparison of Ratios by Earle Lomon
R 3 Making and Using a Scale Drawing by Earle Lomon

3. BIBLIOGRAPHY OF NON-USMES MATERIALS

The following books are references that may be of some use during work on Designing for Human Proportions. The teacher is advised to check directly with the publisher regarding current prices. A list of references on general mathematics and science topics can be found in the *USMES Guide*.

Books for Teachers

Biggs, Edith E. and MacLean, James R. *Freedom to Learn*. Ontario, Canada: Addison-Wesley (Canada) Ltd., 1969.

Chapter 3 of this book may give the teacher some ideas on classroom needs, such as the physical arrangement and the equipment in the room. There are a few designs for storage boxes.

Cope, George and Morrison, Phylis. *The Further Adventures of Cardboard Carpentry*. Watertown, Massachusetts: Workshop for Learning Things (5 Bridge Street, 02172), 1973. ($3.50)

This book presents drawings, photographs, plans and building techniques for making Tri-Wall furniture.

Early Childhood Education Study. *Building with Tubes* and *Building with Cardboard*. Newton, Massachusetts: Education Development Center (Distribution Center, 55 Chapel Street, 02160), 1970. (60¢ each)

These two booklets show how to use heavy cardboard sheets and tubes to make furniture, such as stools, chairs, tables, and storage containers.

Engle, Brenda S. *Arranging the Informal Classroom*. Newton, Massachusetts: Education Development Center (Distribution Center, 55 Chapel Street, 02160), 1973.

Interest areas that make up an open classroom are described in this booklet. Ideas, suggestions, and instructions for arranging an informal classroom are covered. A good bibliography is also included.

Farallones Designs. *Farallones Scrapbook*. Berkeley, California: The Boys in the Back, 1971. (Order from Farallones Designs, Star Route, Point Reyes Station, California 94956.)

Two chapters are well worth examining: "Ways to Change Classrooms" and "Trash Can Do It."

Wastnedge, E. R. (editor) *Nuffield Junior Science, Teacher's Guide 1.* London: William Collins, Sons & Co., Ltd., 1967. (Distributed by Agathon Press, Inc., 150 Fifth Avenue, N.Y., N.Y. 10011.)

The book contains a chapter on classroom organization: arrangement, materials, storage, display space.

4. GLOSSARY

The following definitions may be helpful to a teacher whose class is investigating a Designing for Human Proportions challenge. Some of the words are included to give the teacher an understanding of technical terms; others are included because they are commonly used throughout the resource book.

These terms may be used when they are appropriate for the children's work. For example, a teacher may tell the children that when they conduct surveys, they are collecting *data*. It is not necessary for the teacher or students to learn the definitions nor to use all of these terms while working on their challenge. Rather, the children will begin to use the words and understand the meanings as they become involved in their investigations.

Average — The numerical value obtained by dividing the sum of the elements of a set of data by the number of elements in that set. Also called the mean.

Bias — A deviation in the expected values of a set of data, often occurring when some factor produces one outcome more frequently than others.

Calibration — Setting and marking an instrument to correspond to standard measurements.

Conversion — A change from one form to another. Generally associated in mathematics and science with the change from one unit of measure to another or the change from one form of energy to another.

Correlation — A relationship between two sets of data.

Data — Any facts, quantitative information, or statistics.

Distribution — The spread of data over the range of possible results.

Economics — A social science concerned chiefly with description and analysis of the production, distribution, and consumption of goods and services.

Event — A happening; an occurrence; something that takes place. Example: two children who are 128 cm tall.

Frequency

The number of times a certain event occurs in a given total number of events or in a given unit of time. Example: the number of children in the class who are 128 cm tall.

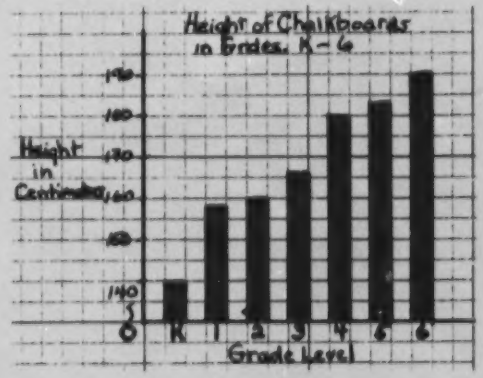
Graph

A drawing or a picture of one or several sets of data.

Bar Graph

A graph of a set of measures or counts whose sizes are represented by the vertical (or horizontal) length of bars of equal widths. Example: heights of chalkboards in grades kindergarten through six.

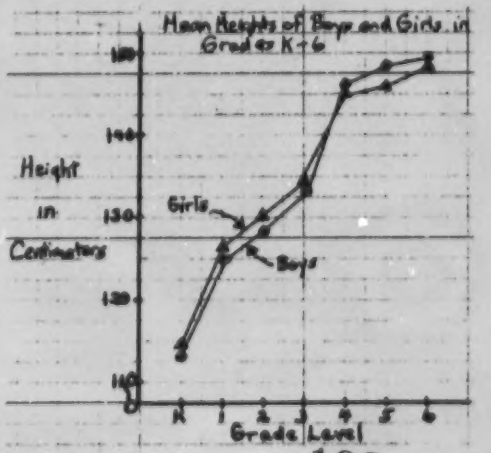
Grade Level	Height (in centimeters)
K	140
1	158
2	160
3	166
4	180
5	183
6	185



A bar graph that is represented by circles, triangles or crosses with lines connecting them so that it has the appearance of a line graph is called a *line chart*. (See *Line Graph*.) This is a useful representation when two or more sets of data are shown on the same graph. Example: comparing the mean heights of boys and girls in grades K-6.

Mean Heights

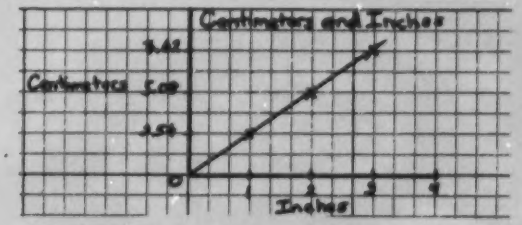
Grade	Boy Height (in cm)	Girl Height (in cm)
K	112	113
1	125	126
2	128	130
3	133	134
4	146	145
5	148	146
6	149	148



Conversion Graph

A line graph that is used to change one unit of measurement to another. For example, converting inches to centimeters.

Inches	Centimeters
1	2.54
2	5.08
3	7.62

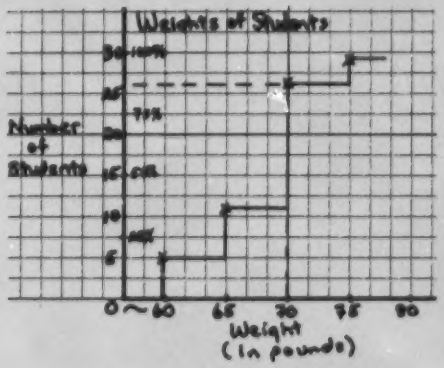


Cumulative Distribution Graph

A graph that can be constructed from a histogram by computing running totals from the histogram data. The first running total is the first value in the histogram data (see table of values). The second running total is the sum of the first and second values of the histogram, the third is the sum of the first, second, and third values, and so on. The horizontal scale on the graph is similar to that of the histogram; the vertical scale goes from 0 to the total number of events observed or samples taken (in the example, the total number of students who weigh seventy pounds or less.)

Each vertical distance on the graph shows the running total of the number of samples taken that are less than or equal to the value shown on the horizontal scale; thus the graph below indicates that twenty-six or about 90% of the students weigh seventy pounds or less.

Weight (in pounds)	Running Totals
60 or less	5
65 or less	11
70 or less	26
75 or less	29

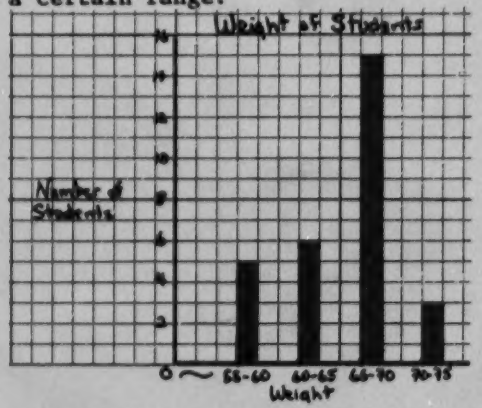


Histogram

Line Graph

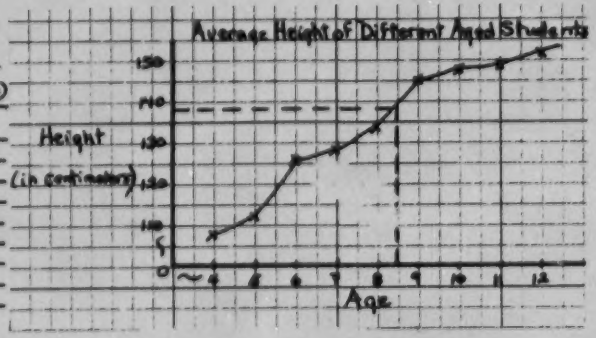
A type of bar graph that shows the distribution of the number of times that different measures or counts of the same event have occurred. A histogram always shows ordered numerical data on the horizontal axis. Example: number of students who weigh within a certain range.

Weight (in pounds)	Number of Students
55-60	5
60-65	6
65-70	15
70-75	3



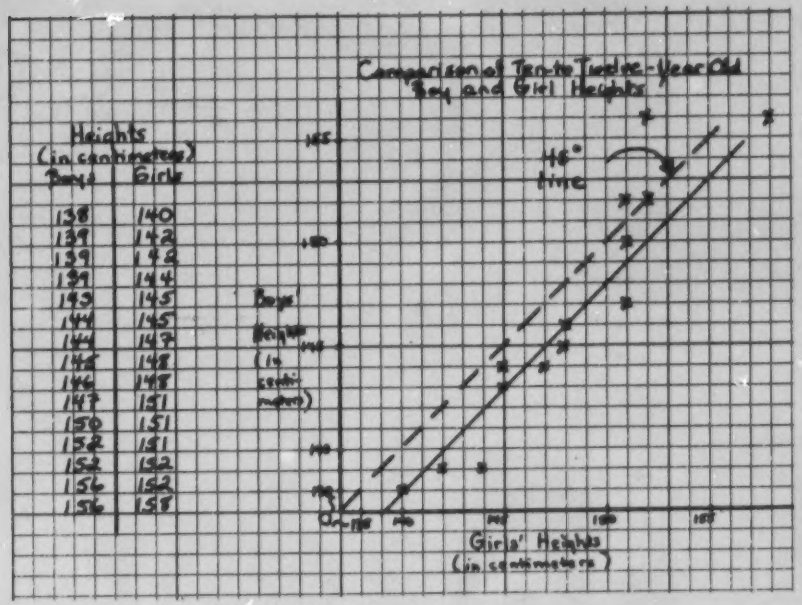
A graph in which a smooth line or line segments pass through or near points representing members of a set of data. Since the line represents an infinity of points, the variable on the horizontal axis must be continuous. If the spaces between the markings on the horizontal axis have no meaning, then the graph is not a line graph, but a line chart (See under *Bar Graph*). Example: the average height of students at different ages. This is a line graph since the height of particular age students can be found by looking at the graph, even though the height was not actually measured at age eight and a half. (dotted line)

Age	Average Height (in centimeters)
4	108
5	112
6	126
7	128
8	133
9	145
10	147
11	149
12	152



Q-Q Graph

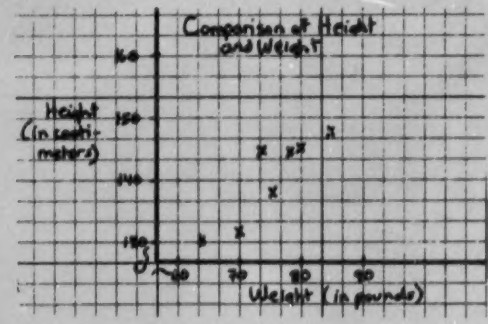
A graph that shows the comparison between the same type of data collected from two groups of people...from two different situations. Example: waist sizes for boys and girls. The data for each set is ordered and the smallest measurement of one set plotted against the smallest of the other set, the second smallest against the second smallest, and so on. The scatter of points is compared to a reference line, a dashed 45° line that represents data from two identical sets.



Scatter Graph

A graph showing a scatter of points, each of which represents two characteristics of the same thing. For example, in the graph below, each point represents one student; the position of the point indicates the student's height and weight.

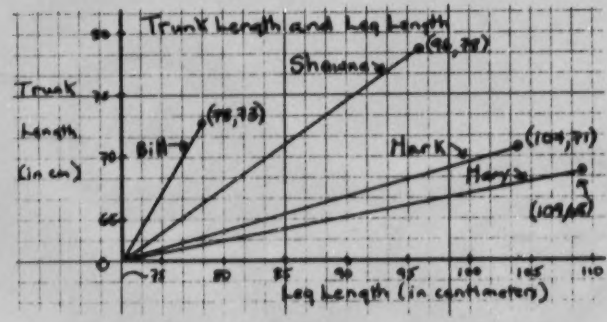
Weight (in lbs)	Height (in cm)
64	130
70	132
72	143
75	137
78	144
80	145
85	148



Slope Diagram*

A graphical means of comparing fractions or ratios. To represent the ratio a/b, plot the point (b,a) and draw a line from (b,a) to the origin, (0,0). The slope of this line represents the ratio a/b. By comparing slopes of several lines, different ratios can be compared; the steeper the line, the larger the ratio. For example, in the diagram showing the ratio of trunk length to leg length, Bill's trunk length to leg length ratio is larger than Shawna, Mark and Mary's trunk length to leg length ratio. Or, Bill is long bodied (short legged).

Student	Trunk Length (in cm)	Leg Length
Mark	71	104
Shawna	78	96
Bill	73	78
Mary	68	109



*Formerly called triangle diagram.

Histogram	See *Graph*.
Hypothesis	A tentative conclusion made in order to test its implications or consequences.
Inference	An assumption derived from facts or information considered to be valid and accurate.
Mean	See *Average*.
Median	The middle value of a set of data in which the elements have been ordered from smallest to largest. The median value has as many elements above it as below it.
Mode	The element or elements in a set of data that occur most often.
Ordered Set	A set of data arranged from smallest to largest.
Per Cent	Literally per hundred. A ratio in which the denominator is always 100, e.g., 72 percent = 72/100 = 0.72 = 72%, where the symbol % represents 1/100.
Percentage	A part of a whole expressed in hundredths.
Proportion	A statement of equality of two ratios, i.e., the first term divided by the second term equals the third term divided by the fourth term, e.g., 5/10 = 1/2. Also a synonym for ratio: when two quantities are in direct proportion, their ratios are the same.
Quartile	
First	The first quartile is the value of the quarter-way piece of data in an ordered set of data.
Third	The third quartile is the value of the three-quarter-way piece of data in an ordered set of data.
Interquartile Range	The range or length of the middle 50% of an ordered set of data; the difference between the first and third quartile.
Range	Mathematical: the difference between the smallest and the largest values in a set of data.
Rank	To order the members of a set according to some criterion, such as size or importance. Example: to put pieces of data from smallest to largest.

Ratio	The quotient of two denominate numbers or values indicating the relationship in quantity, size, or amount between two different things. For example, the ratio of the number of children who can use a piece of furniture to the area occupied by the furniture might be $\frac{10 \text{ children}}{4\frac{1}{2} \text{ square meters}}$ or 10 children:4½ square meters.
Sample	A representative fraction of a population studied to gain information about the whole population.
Sample Size	The number of elements in a sample.
Scale	A direct proportion between two sets of dimensions (as between the dimensions in a drawing of a classroom and the actual classroom).
Scale Drawing	A drawing whose dimensions are in direct proportion to the object drawn.
Scale Map	A map whose dimensions are in direct proportion to the dimensions of the area represented.
Scale Model	A three-dimensional representation constructed to scale.
*Slope Diagram**	See *Graph*
Statistics	The science of drawing conclusions or making predictions using a collection of quantitative data.
Tally	A visible record used to keep a count of some set of data, especially a record of the number of times one or more events occur. Example: number of successful descriptions using five characteristics.

*Formerly called triangle diagram.

E. Skills, Processes, and Areas of Study Utilized in Designing for Human Proportions

The unique aspect of USMES is the degree to which it provides experience in the process of solving real problems. Many would agree that this aspect of learning is so important as to deserve a regular place in the school program even if it means decreasing to some extent the time spent in other important areas. Fortunately, real problem solving is also an effective way of learning many of the skills, processes, and concepts in a wide range of school subjects.

On the following pages are five charts and an extensive, illustrative list of skills, processes, and areas of study that are utilized in USMES. The charts rate Designing for Human Proportions according to its potential for learning in various categories of each of five subject areas--real problem solving, mathematics, science, social science, and language arts. The rating system is based on the amount that each skill, process, or area of study within the subject areas is used--extensive (1), moderate (2), some (3), little or no use (-). (The USMES Guide contains a chart that rates all USMES units in a similar way.)

The chart for real problem solving presents the many aspects of the problem-solving process that students generally use while working on an USMES challenge. A number of the steps in the process are used many times and in different orders, and many of the steps can be performed concurrently by separate groups of students. Each aspect listed in the chart applies not only to the major problem stated in the unit challenge but also to many of the tasks each small group undertakes while working on a solution to the major problem. Consequently, USMES students gain extensive experience with the problem-solving process.

The charts for mathematics, science, social science, and language arts identify the specific skills, processes, and areas of study that may be learned by students as they respond to a Designing for Human Proportions challenge and become involved with certain activities. Because the students initiate the activities, it is impossible to state unequivocally which activities will take place. It is possible, however, to document activities that have taken place in USMES classes and identify those skills and processes that have been used by the students.

Knowing in advance which skills and processes are likely to be utilized in Designing for Human Proportions and knowing the extent that they will be used, teachers can postpone

the teaching of those skills in the traditional manner until later in the year. If the students have not learned them during their USMES activities by that time, they can study them in the usual way. Further, the charts enable a teacher to integrate USMES more readily with other areas of classroom work. For example, teachers may teach fractions during math period when fractions are also being learned and utilized in the students' USMES activities. Teachers who have used USMES for several successive years have found that students are more motivated to learn basic skills when they have determined a need for them in their USMES activities. During an USMES session the teacher may allow the students to learn the skills entirely on their own or from other students, or the teacher may conduct a skill session as the need for a particular skill arises.

Because different USMES units have differing emphases on the various aspects of problem solving and varying amounts of possible work in the various subject areas, teachers each year might select several possible challenges, based on their students' previous work in USMES, for their class to consider. This choice should provide students with as extensive a range of problems and as wide a variety of skills, processes, and areas of study as possible during their years in school. The charts and lists on the following pages can also help teachers with this type of planning.

Some USMES teachers have used a chart similar to the one given here for real problem solving as a record-keeping tool, noting each child's exposure to the various aspects of the process. Such a chart might be kept current by succeeding teachers and passed on as part of a student's permanent record. Each year some attempt could be made to vary a student's learning not only by introducing different types of challenges but also by altering the specific activities in which each student takes part. For example, children who have done mostly construction work in one unit may be encouraged to take part in the data collection and data analysis in their next unit.

Following the rating charts are the lists of explicit examples of real problem solving and other subject area skills, processes, and areas of study learned and utilized in Designing for Human Proportions. Like the charts, these lists are based on documentation of activities that have taken place in USMES classes. The greater detail of the lists allows teachers to see exactly how the various basic skills, processes, and areas of study listed in the charts may arise in Designing for Human Proportions.

The number of examples in the real problem solving list have been limited because the list itself would be unreasonably long if all the examples were listed for some of the categories. It should also be noted that the example(s) in the first category--*Identifying and Defining Problems*--have been limited to the major problem that is the focus of the unit. During the course of their work, the students will encounter and solve many other, secondary problems, such as the problem of how to display their data or how to draw a scale layout.

Breaking down an interdisciplinary curriculum like USMES into its various subject area components is a difficult and highly inexact procedure. Within USMES the various subject areas overlap significantly, and any subdivision must be to some extent arbitrary. For example, where does measuring as a mathematical skill end and measurement as a science and social science process begin? How does one distinguish between the processes of real problem solving, of science, and of social science? Even within one subject area, the problem still remains--what is the difference between graphing as a skill and graphing as an area of study? This problem has been partially solved by judicious choice of examples and extensive cross-referencing.

Because of this overlap of subject areas, there are clearly other outlines that are equally valid. The scheme presented here was developed with much care and thought by members of the USMES staff with help from others knowledgeable in the fields of mathematics, science, social science, and language arts. It represents one method of examining comprehensively the scope of USMES and in no way denies the existence of other methods.

REAL PROBLEM SOLVING	Overall Rating
Identifying and defining problem.	1
Deciding on information and investigations needed.	1
Determining what needs to be done first, setting priorities.	1
Deciding on best ways to obtain information needed.	1
Working cooperatively in groups on tasks.	1
Making decisions as needed.	1
Utilizing and appreciating basic skills and processes.	1
Carrying out data collection procedures--opinion surveying, researching, measuring, classifying, experimenting, construction.	1
Asking questions, inferring	1
Distinguishing fact from opinion, relevant from irrelevant data, reliable from unreliable sources.	1
Evaluating procedures used for data collection and analysis. Detecting flaws in process or errors in data.	1

REAL PROBLEM SOLVING	Overall Rating
Organizing and processing data or information.	1
Analyzing and interpreting data or information.	1
Predicting, formulating hypotheses, suggesting possible solutions based on data collected.	1
Evaluating proposed solutions in terms of practicality, social values, efficacy, aesthetic values.	1
Trying out various solutions and evaluating the results, testing hypotheses.	1
Communicating and displaying data or information.	1
Working to implement solution(s) chosen by the class.	1
Making generalizations that might hold true under similar circumstances; applying problem-solving process to other real problems.	1

KEY: 1 = extensive use, 2 = moderate use, 3 = some use, - = little or no use

MATHEMATICS	Overall Rating
Basic Skills	
Classifying/Categorizing	1
Counting	1
Computation Using Operations:	
Addition/Subtraction	1
Multiplication/Division	1
Fractions/Ratios/Percentages	1
Business and Consumer Mathematics/ Money and Finance	3
Measuring	1
Comparing	1
Estimating/Approximating/Rounding Off	1
Organizing Data	1
Statistical Analysis	1
Opinion Surveys/Sampling Techniques	1
Graphing	1
Spatial Visualization/Geometry	2
Areas of Study	
Numeration Systems	1
Number Systems and Properties	1
Denominate Numbers/Dimensions	1
Scaling	3
Symmetry/Similarity/Congruence	2
Accuracy/Measurement Error/Estimation/ Approximation	1
Statistics/Random Processes/Probability	1
Graphing/Functions	1
Fraction/Ratio	1
Maximum and Minimum Values	3
Equivalence/Inequality/Equations	1
Money/Finance	3
Set Theory	3

SCIENCE	Overall Rating
Process	
Observing/Describing	1
Classifying	2
Identifying Variables	2
Defining Variables Operationally	2
Manipulating, Controlling Variables/ Experimenting	3
Designing and Constructing Measuring Devices and Equipment	1
Inferring/Predicting/Formulating, Testing Hypotheses/Modeling	1
Measuring/Collecting, Recording Data	1
Organizing, Processing Data	1
Analyzing, Interpreting Data	1
Communicating, Displaying Data	1
Generalizing/Applying Process to New Problems	1
Areas of Study	
Measurement	1
Motion	-
Force	3
Mechanical Work and Energy	3
Solids, Liquids, and Gases	2
Electricity	-
Heat	-
Light	-
Sound	-
Animal and Plant Classification	-
Ecology/Environment	-
Nutrition/Growth	-
Genetics/Heredity/Propagation	3
Animal and Plant Behavior	-
Anatomy/Physiology	2

KEY: 1 = extensive use, 2 = moderate use, 3 = some use, - = little or no use

SOCIAL SCIENCE	Overall Rating
Process	
Observing/Describing/Classifying	2
Identifying Problems, Variables	1
Manipulating, Controlling Variables/ Experimenting	3
Inferring/Predicting/Formulating, Testing Hypotheses	2
Collecting, Recording Data/Measuring	2
Organizing, Processing Data	2
Analyzing, Interpreting Data	2
Communicating, Displaying Data	2
Generalizing/Applying Process to Daily Life	2
Attitudes/Values	
Accepting responsibility for actions and results	1
Developing interest and involvement in human affairs	1
Recognizing the importance of individual and group contributions to society	1
Developing inquisitiveness, self-reliance, and initiative	1
Recognizing the values of cooperation, group work, and division of labor	1
Understanding modes of inquiry used in the sciences, appreciating their power and precision	1
Respecting the views, thoughts, and feelings of others	1
Being open to new ideas and information	1
Learning the importance and influence of values in decision making	1
Areas of Study	
Anthropology	-
Economics	3
Geography/Physical Environment	-
Political Science/Government Systems	3
Recent Local History	-
Social Psychology/Individual and Group Behavior	-
Sociology/Social Systems	3

LANGUAGE ARTS	Overall Rating
Basic Skills	
Reading	
Literal Comprehension: Decoding Words, Sentences, Paragraphs	3
Critical Reading: Comprehending Meanings, Interpretation	3
Oral Language	
Speaking	1
Listening	1
Memorizing	-
Written Language	
Spelling	3
Grammar: Punctuation, Syntax, Usage	3
Composition	3
Study Skills	
Outlining/Organizing	3
Using References and Resources	3
Attitudes/Values	
Appreciating the value of expressing ideas through speaking and writing	1
Appreciating the value of written resources	3
Developing an interest in reading and writing	3
Making judgments concerning what is read	3
Appreciating the value of different forms of writing, different forms of communication	1

KEY: 1 = extensive use, 2 = moderate use, 3 = some use, - = little or no use

REAL PROBLEM SOLVING IN DESIGNING FOR HUMAN PROPORTIONS

Identifying and Defining Problems	• Students note that classroom worktables are either too high or too low. • See also SOCIAL SCIENCE list: *Identifying Problems, Variables.*
Deciding on Information and Investigations Needed	• Students decide that they need to measure the existing worktable heights. • Students decide that they need to collect body measurements. • Students decide that they need to determine table style preferences.
Determining What Needs to Be Done First, Setting Priorities	• Students decide to determine worktable style preferences before collecting body measurements. • Students decide what body measurements are necessary for a comfortable fit before measuring. • Students decide before conducting survey on preferences what worktables are feasible to construct.
Deciding on Best Ways to Obtain Information Needed	• Students decide to conduct an opinion survey to determine worktable style preferences. • Students decide on best procedures for gathering body measurements.
Working Cooperatively in Groups on Tasks	• Small groups work on conducting the opinion survey. • Small groups work on collecting various body measurements.
Making Decisions as Needed	• Students decide that three different worktable heights will fit most students in the class. • Students decide to represent their measurement data on graphs.
Utilizing and Appreciating Basic Skills and Processes	• Students draw graphs of their measurement data. • Students make a scale model of the worktable design. • Students compare the capabilities and limitations of using wood and Tri-Wall for the worktables. • Students design an opinion survey to determine worktable design preference.

Utilizing and Appreciating Basic Skills and Processes (cont.)	• Students use the telephone to call several lumber stores to compare lumber prices. • Small groups report group activities to the class. • See also MATHEMATICS, SCIENCE, SOCIAL SCIENCE, and LANGUAGE ARTS lists.
Carrying Out Data Collection Procedures--Opinion Surveying, Researching, Measuring, Classifying, Experimenting, Constructing	• Students measure waist-to-floor distance on their sample population. • Students conduct opinion survey on desirable design features. • Students observe and measure different worktable sizes and styles. • See also MATHEMATICS list: *Classifying/Categorizing; Measuring.* • See also SCIENCE list: *Observing/Describing; Classifying; Manipulating, Controlling Variables/Experimenting; Designing and Constructing Measuring Devices and Equipment; Measuring/Collecting, Recording Data.* • See also SOCIAL SCIENCE list: *Observing/Describing/Classifying; Manipulating, Controlling Variables/Experimenting; Collecting, Recording Data/Measuring.*
Asking Questions, Inferring	• Students question the number of worktable heights that are needed to fit everyone in the class. They infer from the graphed data that three different heights would fit most students. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.* • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*
Distinguishing Fact from Opinion, Relevant from Irrelevant Data, Reliable from Unreliable Sources	• Students recognize that merchants are reliable sources for information on prices of building materials.
Evaluating Procedures Used for Data Collection and Analysis, Detecting Flaws in Process or Errors in Data	• Students discover that one small group rounded the waist-to-floor measurements to the nearest whole centimeter and that other groups didn't. • See also MATHEMATICS list: *Estimating/Approximating/Rounding Off.*

Organizing and Processing Data	• Students order the measurement data from shortest to tallest to draw histograms. • Students tally the results from the opinion survey on worktable preferences. • See also MATHEMATICS list: *Organizing Data.* • See also SCIENCE and SOCIAL SCIENCE lists: *Organizing, Processing Data.*
Analyzing and Interpreting Data	• Students make a histogram of the waist-to-floor measurements, then determine obvious groups of measurements. • Students calculate a preference rating for each design to determine which design is liked the best. • See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Maximum and Minimum Values; Graphing.* • See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data.*
Predicting, Formulating Hypotheses, Suggesting Possible Solutions Based on Data Collection	• Students hypothesize that three different table heights will fit most students in the class. • Students predict that some styles will be more popular than others because of certain features. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.* • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*
Evaluating Proposed Solutions in Terms of Practicality, Social Values, Efficacy, Aesthetic Values	• Students discuss the advantages and disadvantages of various worktable designs. • Students investigate the cost of materials needed to construct the worktables.
Trying Out Various Solutions and Evaluating the Results, Testing Hypotheses	• Students construct scale models of the designs to test for sturdiness and to determine which tables can be built easily. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.* • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*

Communicating and Displaying Data or Information	• Students draw a bar graph to show student preference for various table designs. • Students draw a histogram to show the distribution of floor-to-waist measurements. • See also MATHEMATICS list: *Graphing; Scaling.* • See also SCIENCE and SOCIAL SCIENCE lists: *Communicating, Displaying Data.* • See also LANGUAGE ARTS list.
Working to Implement Solution(s) Chosen by the Class	• Students construct the three sizes of tables.
Making Generalizations That Might Hold True Under Similar Circumstances; Applying Problem-Solving Process to Other Real Problems	• Students recognize that items used by people, such as playground equipment, furniture, and clothing, require consideration of body proportions. • Students utilize measuring and graphing skills (acquired while working on the Designing for Human Proportions challenge) on other USMES challenges.

Basic Skills

Classifying/Categorizing	• Establishing groupings of measurements, such as tall, medium, short. • Establishing sizes based on measurements. • See also SCIENCE list: *Classifying*. • See also SOCIAL SCIENCE list: *Observing/Describing/Classifying*.
Counting	• Counting hand votes to determine priorities of tasks. • Counting survey data on style preference. • Counting the number of items that have been requested. • Counting the number of students who wish to work on various tasks. • Counting to read scales on measuring instruments, such as rulers, meter sticks. • Counting by sets to find scale for graph axes.
Computation Using Operations: Addition/Subtraction	• Adding one-, two-, or three-digit whole numbers to find total tally or total measurement. • Subtracting one-, two-, or three-digit whole numbers to find differences between predicted and actual measurements. • Subtracting one-, two-, or three-digit whole numbers to find ranges for measurements. • Subtracting one-, two-, or three-digit whole numbers to find measurement differences among students in the class, among students in different grade levels. • Subtracting one-, two-, or three-digit whole numbers to determine the amount measurements deviate from the median or mean measurement.
Computation Using Operations: Multiplication/Division	• Multiplying one-, two-, or three-digit whole numbers to find total amount of material needed. • Multiplying or dividing one-, two-, or three-digit whole numbers to convert from one unit of measure to another, such as meters to centimeters, inches to centimeters, and vice versa.

Computation Using Operations: Multiplication/Division (cont.)	• Dividing one-, two-, or three-digit whole numbers to decrease measurements for scale drawings or scale models. • Dividing one-, two-, or three-digit whole numbers to determine mean measurements. • Dividing and multiplying one-, two-, or three-digit whole numbers to determine percentage of students in the school who have certain preferences or certain measurements. • Dividing one- or two-digit whole numbers to determine the number of items that must be made each session in order to complete the total number needed.
Computation Using Operations: Fractions/Ratios/Percentages	• Using mixed numbers in adding, subtracting, multiplying, or dividing measurements. • Changing fractions to higher or lower terms (equivalent fractions) to add, subtract, multiply, or divide measurements. • Using fractions and ratios to convert from one unit of measure to another, such as centimeters to meters. • Using fractions in graphing measurements. • Using ratios to increase or decrease measurements for scale drawings or scale models. • Calculating percentage of students who prefer certain designs or who have certain measurements. • Using slope diagrams to compare ratios and fractions, such as the ratio of height measurement to reach measurement.
Computation Using Operations: Business and Consumer Mathematics/ Money and Finance	• Adding, subtracting, multiplying and dividing dollars and cents to perform a cost analysis on materials needed. • Gaining experience with finances: sources, uses, and limitations of revenues for materials needed. • Multiplying or dividing to find total cost or unit cost. • Comparing price, quality, and quantity when shopping for fabric or lumber.
Measuring	• Using standard (centimeters, pounds) and nonstandard (string lengths) units of measure. • Using different measuring instruments to gather body and furniture measurements, such as tape measures, meter sticks, calipers. • Reading measuring instruments accurately. • Converting from one unit of measure to another, such as centimeters to meters.

Measuring (cont.)	• See also SCIENCE list: *Measuring/Collecting, Recording Data.* • See also SOCIAL SCIENCE list: *Collecting, Recording Data/ Measuring.*
Comparing	• Using the concept of *greater than* and *less than* in making comparisons of measurement. • Comparing quantitative data, such as measurements of several heights taken by various students, prices of materials from several stores. • Comparing the mean, mode, and median of measurement data. • Comparing student heights by putting students back to back or side by side. • Comparing the costs of various designs, different building materials, etc. • Comparing measurement data graphically, as with a scatter graph (chest width to collarbone-to-waist), histogram (height distribution), or bar graph (bulletin board heights in grades K-6). • Comparing fractions and ratios using the slope diagram. • See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data.*
Estimating/Approximating / Rounding Off	• Estimating the number of students who may want a smock, who may want to work at a table, who may want lower drinking fountains. • Estimating one body measurement from knowledge of another body measurement, such as estimating reach from height measurement. • Determining when a measurement is likely to be accurate enough for a particular purpose. • Rounding off measurements while measuring various body parts.
Organizing Data	• Ordering measurement data from shortest to tallest. • Tallying measurement data onto a chart or graph form. • Ordering real numbers on a graph axis. • See also SCIENCE and SOCIAL SCIENCE lists: *Organizing, Processing Data.*
Statistical Analysis	• Determining the total range of measurement data; determining groupings within the total distribution of measurement data; determining the range of each grouping.

Statistical Analysis (cont.)

- Finding medians, means, and modes of measurement data.
- Determining how much each measurement grouping deviates from the mean or median.
- Interpreting scatter graphs, bar graphs, and histograms.
- Assessing predictability of a larger sample (students in the school) based on results from a smaller sample (five students from each class in grades K-6).
- See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data*.

Opinion Surveys/Sampling Techniques

- Conducting opinion surveys, defining data collection methods, makeup and size of sample.
- Devising methods of obtaining quantitative information about subjective opinions, such as calculating a preference rating for each question on a survey.
- Evaluating survey methods, data obtained, size and type of sample.
- See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data*.

Graphing

- Using graphs to display data; making the graph form--dividing axes into parts, deciding on an appropriate scale.
- Representing data on graphs.
  - Bar graph--mean measurements of students in each grade from kindergarten through sixth.
  - Conversion graph--changing of inches to centimeters.
  - Cumulative distribution graph--percentages of students who have a certain measurement that is less than or equal to a given value.
  - Histogram--numbers of students who have certain measurements.
  - Line graph--average measurements of students at different ages.
  - Q-Q graph--comparison of certain measurements for boys with measurements of the same thing for girls.
  - Scatter graph--one measurement vs. another measurement for one person.
  - Slope diagram--comparison of one measurement with another measurement.
- Obtaining information from graphs.
- See also SCIENCE and SOCIAL SCIENCE lists: *Communicating, Displaying Data*.

Spatial Visualization/Geometry	• Drawing and building a scale model of the various designs. • Comparing geometric shapes of items being produced. • Using standard mensurational formulas when calculating areas. • Using the concept of *greater than* and *less than* to compare geometric figures, such as squares, rectangles, circles.

Areas of Study

Numeration Systems	• Using the metric system (decimal system) to collect measurement data, to calculate cost of materials. • Using the English system (other bases, such as fractions of inches) to collect measurement data. • See *Computation Using Operations: Fractions/Ratios/Percentages*.
Number Systems and Properties	• See *Computation Using Operations*.
Denominate Numbers/Dimensions	• See *Measuring*.
Scaling	• Deriving information from a scale drawing. • Finding an appropriate scale (ratio) for the scale drawing or scale model.
Symmetry/Similarity/Congruence	• See *Spatial Visualization/Geometry*.
Accuracy/Measurement Error/ Estimation/Approximation	• See *Measuring* and *Estimating/Approximating/Rounding Off*.
Statistics/Random Processes/ Probability	• See *Statistical Analysis*.
Graphing/Functions	• See *Graphing*.
Fraction/Ratio	• See *Computation Using Operations: Fractions/Ratios/Percentages*.

Maximum and Minimum Values	• Determining sizes that will comfortably fit the most students in the school. • Determining the height of items that will fit most students in the class. • Finding a design that would be the cheapest to produce, easiest to construct.
Equivalence/Inequality/Equations	• See *Comparing* and *Computation Using Operations*.
Money/Finance	• See *Computation Using Operations: Business and Consumer Mathematics/Money and Finance*.
Set Theory	• See *Classifying/Categorizing*.

ACTIVITIES IN DESIGNING FOR HUMAN PROPORTIONS UTILIZING SCIENCE

Process

Observing/Describing	• Observing and describing items that do not fit properly. • Observing and describing characteristics of clothing or classroom furniture. • See also SOCIAL SCIENCE list: *Observing/Describing/Classifying.*
Classifying	• Classifying items according to the number of body measurements that need to be considered in order to change the item to be a good fit, e.g., smock sizes (several) vs. pencil sharpener height (one). • Distinguishing between primary and intermediate furniture. • See also MATHEMATICS list: *Classifying/Categorizing.* • See also SOCIAL SCIENCE list: *Observing/Describing/Classifying.*
Identifying Variables	• Identifying dimensions that may vary according to size, e.g., width, length, and distance around in different sizes of clothing. • Identifying variable(s) that have to be measured, such as students' reach (for height of bulletin board). • Identifying variables that affect measurement data, such as whether children's shoes are on or off when measuring height. • See also SOCIAL SCIENCE list: *Identifying Problems, Variables.*
Defining Variables Operationally	• Defining a "good" fit by deciding how much a critical measurement may deviate from the mean or median measurement. • Defining a popular style as one that 75% of the student population has chosen as their favorite. • Defining a waist-to-floor measurement as the distance (rounded off to the nearest centimeter) from the top of a student's belt to the floor when the student is wearing his/her usual shoes; defining other body measurements similarly.

Manipulating, Controlling Variables/Experimenting	• Collecting measurement data according to specified procedures. • Testing each prototype or design for good fit. • Testing each furniture design model for overall strength and stability. • See also SOCIAL SCIENCE list: *Manipulating, Controlling Variables/Experimenting.*
Designing and Constructing Measuring Devices and Equipment	• Designing and constructing measuring instruments (e.g., calipers) in the Design Lab.
Inferring/Predicting/Formulating, Testing Hypotheses/Modeling	• Inferring from the histogram that certain sizes will fit all the students in the class. • Making scale models of the designs to determine which design best suits their needs. • Conducting trials of placement and size of designs to determine if fit is good. • Inferring from a scatter graph that there is (or is not) a correlation between two body measurements, such as trunk length and leg length. • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*
Measuring/Collecting, Recording Data	• Weighing children with weight scales; reading results accurately. • Recording measurements in an organized manner. • See also MATHEMATICS list: *Measuring.* • See also SOCIAL SCIENCE list: *Collecting, Recording Data/Measuring.*
Organizing, Processing Data	• Ordering the tasks that need to be done in terms of priority. • Ordering building materials according to some criterion, such as the cheapest, easiest to work with, most durable, etc. • See also MATHEMATICS list: *Organizing Data.* • See also SOCIAL SCIENCE list: *Organizing, Processing Data.*

Analyzing, Interpreting Data

- Analyzing results from tests done on models of several designs.
- See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Graphing; Maximum and Minimum Values.*
- See also SOCIAL SCIENCE list: *Analyzing, Interpreting Data.*

Communicating, Displaying Data

- Reporting data to the class.
- Representing quantitative data on graphs or charts.
- See also MATHEMATICS list: *Graphing.*
- See also SOCIAL SCIENCE list: *Communicating, Displaying Data.*
- See also LANGUAGE ARTS list.

Generalizing/Applying Process to New Problems

- Applying scientific inquiry process (e.g., identifying a problem, identifying important aspects of the problem, etc.) to tackle other real problems and other USMES challenges.
- Applying data collection and analysis process to problems in human proportions arising in Play Area Design and Use, Manufacturing, or Classroom Design.
- Applying testing process to problems on materials arising in Consumer Research, Manufacturing, or School Supplies.
- See also SOCIAL SCIENCE list: *Generalizing/Applying Process to Daily Life.*

Areas of Study

Measurement

- Understanding the concept of a unit of measure.
- Using standard (centimeters, pounds) and nonstandard (string lengths) units of measure.
- Picking the best instrument to use to measure body parts and furniture, e.g., tape measure, meter stick, calipers, weight scales.
- Designing measuring tools for specific uses, e.g., foot measuring device, adjustable table height measurer.
- Recognizing that repeated measurements of a distance produces distributions, rather than one value.
- See also MATHEMATICS list: *Measuring.*

Motion

Speed/Velocity	• Observing that electrically-run machines (saber saws, sewing machines, duplicating machines) are faster than hand machines.
Force	• Observing that more force must be exerted when cutting several pieces of fabric at one time. • Observing that saber saws are faster and require less effort to operate than hand saws for cutting Tri-Wall or lumber and multiply the force that is exerted. • Observing that force must be exerted to hammer nails into wood, that the hammer multiplies the force exerted.
Friction	• Observing that the wood surface offers less resistance to the motion of the sandpaper as the wood becomes smoother. • Observing that a blade becomes warmer as the sawing motion becomes more vigorous because doing work against the force of friction generates heat.
Mechanical Work and Energy	• Observing that wood blocks become warm when sanded vigorously as mechanical energy is transformed into heat energy. • Observing that energy is expended while hammering nails, painting. • See also *Motion* and *Force*.

Solids, Liquids, and Gases

States of Matter	• Observing that glue is available in liquid or solid form with different properties. • Observing that a solid stick of glue is turned into hot liquid glue by using a hot glue gun.
Properties of Matter	• Noting the capabilities and limitations of using and working with various materials (lumber, Tri-Wall). • Observing the different densities and colors of fabrics and other materials. • Observing the effects of physical wear on materials, such as Tri-Wall, fabric. • Observing that glues, lumber, paper, fabric, and other materials have particular odors.

Electricity	• Observing that the saber saw goes on when the switch is closed and goes off when the switch is opened. • Observing that electricity can be transformed into mechanical energy (saber saw, sewing machine), and heat energy (glue gun, iron).
Light	• Observing that fabrics and paints come in different colors.
Genetics/Heredity/Propagation	• Examining differing and like physical characteristics. • Noting that most children have physical characteristics similar to those of their parents.
Anatomy/Physiology	• Observing bone structures and body proportions and noting that big-boned children may be the same height as small-boned children. • Observing differing and like physical characteristics. • Measuring body parts, e.g., height, waist circumference, chest width.

ACTIVITIES IN DESIGNING FOR HUMAN PROPORTIONS IN SOCIAL SCIENCE

Process

Observing/Describing/Classifying	• Observing and accurately describing like and differing physical characteristics. • Classifying students according to similar physical characteristics, to similar preferences for a worktable design, etc. • Classifying people in one or more ways, e.g., by age, sex, grade level. • See also MATHEMATICS list: *Classifying/Categorizing.* • See also SCIENCE list: *Observing/Describing; Classifying.*
Identifying Problems, Variables	• Identifying the problem of finding a suitable worktable height or smock size that would fit everyone in the class. • Identifying body dimensions (waist circumference, height, chest width) that can change from one person to another. • Identifying variables (age, grade level) that affect the design and the results of an opinion survey. • See also SCIENCE list: *Identifying Variables.*
Manipulating, Controlling Variables/Experimenting	• Standardizing measuring methods among students. • Experimenting with different table heights to determine student preference: having students stand next to the different table heights and pretend to work. • See also SCIENCE list: *Manipulating, Controlling Variables/Experimenting.*
Inferring/Predicting/Formulating, Testing Hypotheses	• Predicting from a histogram that there will be a number of student measurements that will be very large or small; deciding what to do with these extremes. • Inferring from the opinion survey which problems are urgent, which design is popular, etc. • Deciding that, based on waist-to-floor measurements, two worktables will accommodate the class. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*

Collecting, Recording Data/ Measuring	• Conducting an opinion survey. • See also MATHEMATICS list: *Counting; Measuring.* • See also SCIENCE list: *Measuring/Collecting, Recording Data.*
Organizing, Processing Data	• Tallying votes for individual designs. • Arranging designs in order of preference based on opinion survey results. • See also MATHEMATICS list: *Organizing Data.* • See also SCIENCE list: *Organizing, Processing Data.*
Analyzing, Interpreting Data	• Making side by side comparisons. • Evaluating the way the opinion survey was administered. • Comparing primary and intermediate student responses on the opinion survey. • See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Graphing; Maximum and Minimum Values.* • See also SCIENCE list: *Analyzing, Interpreting Data.*
Communicating, Displaying Data	• Reporting group activities to the class. • Representing survey data on preferences on graphs or charts. • See also MATHEMATICS list: *Graphing.* • See also SCIENCE list: *Communicating, Displaying Data.* • See also LANGUAGE ARTS list.
Generalizing/Applying Process to Daily Life	• Applying one's knowledge of opinion surveys to other opinion surveys. • See also SCIENCE list: *Generalizing/Applying Process to New Problems.*
Attitudes/Values	
Accepting Responsibility for Actions and Results	• Working in small groups to perform tasks. • Arranging schedules with other classes for convenient times for opinion surveys and measuring. • Being responsible for shopping plans: writing a list of needed materials and stores to shop, arranging convenient times for both teacher and students, obtaining the necessary permissions, etc.

Accepting Responsibility for Actions and Results (cont.)	• Scheduling and giving a presentation to the school principal and school faculty and staff.
Developing Interest and Involvement in Human Affairs	• Seeking ways to lower the chalkboard so that students may use it more comfortably and effectively; seeking ways to make Design Lab smocks fit students of different sizes so that they may work more comfortably.
Recognizing the Importance of Individual and Group Contributions to Society	• Recognizing that they can improve the classroom and various aspects of the school. • Recognizing that the improved height of the chalkboard or the different sizes of work smocks will help others work more comfortably and effectively.
Developing Inquisitiveness, Self-Reliance, and Initiative	• Conducting group sessions with some teacher assistance. • Learning to use different ways of obtaining needed information, e.g., letter writing, opinion surveying, telephoning. • Increasing their knowledge of places that are possible resources, e.g., library, retail stores. • Resolving procedural problems that may arise during the course of activities. • Choosing and designing the best way of presenting to the principal their proposal to change the chalkboard height.
Recognizing the Values of Cooperation, Group Work, and Division of Labor	• Recognizing the efficiency that small group work provides, e.g., in collecting numerous body measurements. • Finding that work proceeds smoothly when everyone cooperates.
Understanding Modes of Inquiry Used in the Sciences, Appreciating Their Power and Precision	• Identifying and defining the problem; being able to distinguish it from related but secondary problems. • Identifying important aspects of the problem and setting priorities. • See also MATHEMATICS and SCIENCE lists.
Respecting the Views, Thoughts, and Feelings of Others	• Considering all suggestions and ideas and assessing their merit.

Respecting the Views, Thoughts, and Feelings of Others (cont.)	• Recognizing differences in values according to age, experience, occupation, income, interests, culture, race, religion, ethnic background. • Considering the opinions of others; conducting opinion surveys to determine style preference.
Being Open to New Ideas and Information	• Considering suggestions and ideas from all students, considering other ways of doing various tasks. • Recognizing the importance of information obtained from different sources, e.g., library, retail stores.
Learning the Importance and Influence of Values in Decision Making	• Recognizing that people's values and feelings are equally or more important than cost considerations when proposing change. • Recognizing that differences of opinion reflect value differences. • Realizing that preferences for various designs reflect individual values.
Areas of Study	
Economics	• Using economic concepts and terms, e.g., cost, retail and wholesale price. • Gaining experience with finance: sources, uses, and limitations of revenues for the purchase of materials. • Assessing preferences of possible consumers through opinion surveys. • Gaining experience in comparative shopping for materials.
Political Science/Government Systems	• Investigating the school system of administration and control, school rules and regulations (e.g., permission to leave school during the day to shop for materials).
Recent Local History	• Investigating complaints and problems with various classroom furnitures and fixtures, clothing items; finding out what action, if any, had been taken.

Social Psychology/Individual and Group Behavior	• Recognizing that physical characteristics may unduly influence an individual's self-image and behavior towards others. • Respecting everyone's different physical characteristics. • Recognizing the need for leadership within small and large groups; recognizing differing capacities of individuals for various roles within groups. • Finding the "best" way to approach the principal about changing chalkboard heights, retail store personnel to ask for advice, etc. • Analyzing the effects of a small group (one class) making decisions for a larger group (the whole school).
Sociology/Social Systems	• Devising a system of working cooperatively in small and large groups. • Investigating problems and making changes that affect other students in the school. • Recognizing peer groups as social systems--differences in classroom furniture and needs between primary and intermediate students. • Recognizing different social systems in different social groups, e.g., students, retail store managers, homemakers. • Recognizing that there are many different social groups and that one person belongs to more than one social group.

ACTIVITIES IN DESIGNING FOR HUMAN PROPORTIONS IN LANGUAGE ARTS

Basic Skills

Reading: Literal Comprehension--Decoding Words, Sentences, and Paragraphs	• Decoding words, sentences, and paragraphs while reading drafts of letters to the school principal, catalogs of building materials, the yellow pages of the telephone book, advertisements for building materials on sale, etc.
Reading: Critical Reading--Comprehending Meanings, Interpretation	• Reading and comparing different advertisements for the same material. • Evaluating drafts of letters, opinion surveys.
Oral Language: Speaking	• Offering ideas, suggestions, and criticisms during class discussions. • Reporting to class on procedures used to measure various body parts. • Making arrangements with other teachers in the school to conduct the opinion survey in their classes. • Making a presentation on reasons for changing the chalkboard heights before the school principal and staff. • Conducting a simple one- or two-question opinion survey: reading the questions aloud, recording the show of hands. • Using the telephone to obtain information. • Using rules of grammar in speaking.
Oral Language: Listening	• Listening to other students' ideas, suggestions, and criticisms during class discussions; listening while conducting a poll in other classes. • Listening to experts' suggestions and recommendations for constructing the worktables or the smocks.
Written Language: Spelling	• Using correct spelling in writing, e.g., writing a letter to the principal, labeling graphs.

Written Language: Grammar--Punctuation, Syntax, Usage	• Using rules of grammar in writing, e.g., in writing letters to parents asking for assistance or materials.

Written Language: Composition	• Writing to communicate effectively:
	  • preparing written reports and letters using notes, data and graphs.
	  • writing down opinion surveys; devising questions to elicit the desired information; judging whether a question is relevant and whether its meaning is clear.

Study Skills: Outlining/Organizing	• Organizing data for inclusion in a letter or presentation. • Planning and preparing letters, presentations. • Making a list of tasks that need to be done. Setting priorities for tasks.
Study Skills: Using References and Resources	• Using the local stores and personnel as resources for ideas. • Using the telephone book to look up lumber, fabric, and hardware stores. • Contacting experts for assistance, e.g., a mother who sews well, a carpenter who can assist in the Design Lab. • Using the "How To" Cards on specific skills when needed.
Attitudes/Values	
Appreciating the Value of Expressing Ideas Through Speaking and Writing	• Finding that an adequate oral presentation or a written letter evokes a response from people, e.g., the principal.
Appreciating the Value of Written Resources	• Finding that desired information can be found in written resources, such as supplies catalogs, telephone book.
Developing an Interest in Reading and Writing	• Appreciating written resources as a source for ideas. • Showing willingness to find information in catalogs.

Making Judgments Concerning What is Read	• Evaluating opinion survey questions, drafts of letters. • Deciding how much of an advertisement for materials is true.
Appreciating the Value of Different Forms of Writing, Different Forms of Communication	• Finding that the telephone is a useful and efficient tool to obtain information from local stores. • Finding that an oral presentation may be better in some cases, while a written letter may be better in others.